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Source Rocks and Sediments in Drainage Area of North Eden Creek, Bear Lake Plateu, Utah-Idaho

Larry W. McClurg

SOURCE ROCKS AND SEDIMENTS IN DRAINAGE

AREA OF NORTH EDEN CREEK, BEAR

LAKE PLATEAU, UTAH-IDAHO

by

Larry W. McClurg

A thesis submitted in partial fulfillment
of the requirements for the degree

of

MASTER OF SCIENCE

in

Geology

Approved:

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Major Professor

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Committee Member

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Committee Member

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Dean of Graduate Studies

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Logan, Utah

1970

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Larry W. McClurg

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF FIGURES

LIST OF PLATES

ABSTRACT

Source Rocks and Sediments in Drainage Area of North Eden Creek, Bear Lake Plateau, Utah-Idaho

by

Larry W. McClurg

Utah State University, 1970

Major Professor: Dr. Robert Q. Oaks, Jr.
Department: Geology

The Bear Lake Plateau extends north-south across the north-central corner of Utah and the southeastern corner of Idaho. North Eden Creek drains westward through part of the plateau and is cross-axial across both strikes of beds and other structures in the area. The formations in the area mapped are of Triassic, Jurassic, and Tertiary age, although only Jurassic and Tertiary rocks contribute sediments to North Eden Creek. The formations consist of sandstones (Nugget), limestones (Twin Creek), and conglomerates (Wasatch). A local extrusion of basalt occurs in the southwestern part of the drainage area.

Particle-size analyses of 15 samples from pits dug along North Eden Creek and its tributaries and North Eden Delta show that mean and maximum particle sizes increase downstream due to additions by tributaries and mass-wasting from the coarse-grained, highly jointed Nugget Formation flanking lower parts of the stream.

Mineralogic analyses of these samples show that quartzite and chert predominate in the gravel sizes and that quartz and calcite

predominate in the sand and silt sizes; kaolinite is the dominant mineral in the clay sizes. Feldspar and dolomite also are present in small quantities. Amorphous material, a common constituent in the sediment of Bear Lake, is abundant in sizes < .00049 mm. The calcite supplied to Bear Lake as clay-sized particles indicates that clay-sized calcite in Bear Lake is at least partly detrital.

(92 pages)

INTRODUCTION

General Statement

This report summarizes a geologic investigation of rock types present and sediment transported within the drainage area of North Eden Creek, just east of Bear Lake, Utah-Idaho (Figure 1). A large delta at the mouth of North Eden Canyon (Figure 2) shows that this drainage has been a major source of sediments carried into Bear Lake.

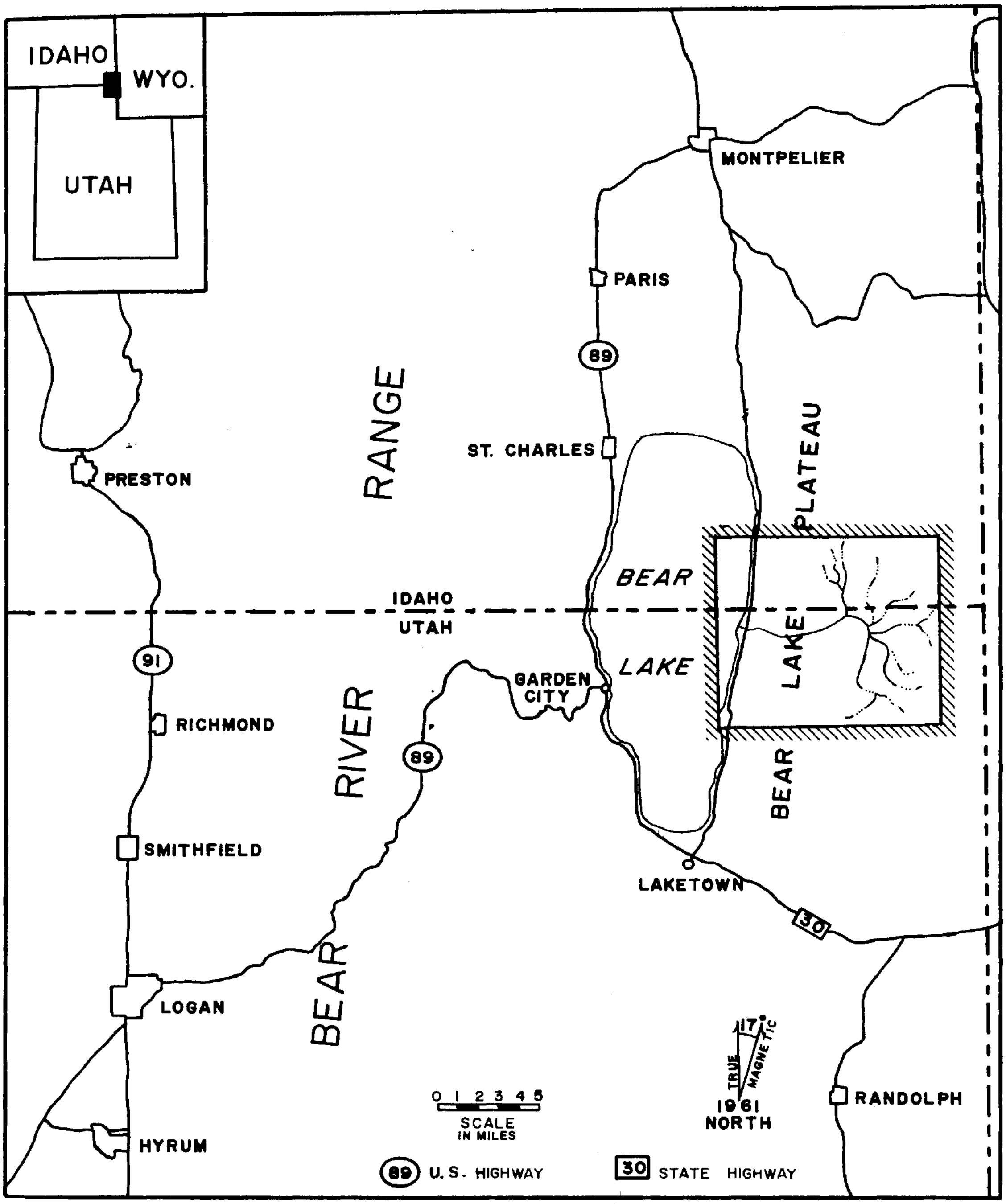
Purpose of Investigation

The purpose of this investigation was to study the drainage area of North Eden Creek in order to identify lithologies subject to erosion and mineralogy of sediments transported by the creek. Only by studies of this sort can the source (provenance) of minerals found in sediments of Bear Lake be determined.

Previous work (Davidson, 1969) showed the presence of aragonite, calcite, and dolomite in sediments of Bear Lake. Aragonite is actively precipitated by both organic and chemical action. Calcite, dolomite, and chemically precipitated aragonite occur in the clay-sized fraction of lake sediments. One major objective of the present study was to determine whether calcite and dolomite are brought into Bear Lake as detrital particles of clay size.

The primary objectives of this study were: (1) To construct a map showing distributions of different rock types (lithologies); (2) To sample stream sediments at tributary junctions; and (3) To

Figure 1. Index map showing area mapped in Plate 1, drainage of North Eden Creek, Bear Lake, and other localities mentioned in the text, in north-central Utah, southeastern Idaho, and southwestern Wyoming.


IDAHO
WYO.
UTAH
MONTPELIER
PARIS
89
RANGE
ST. CHARLES
PRESTON
PLATEAU
BEAR
IDAHO
UTAH
LAKE
91
GARDEN CITY
LAKE
RICHMOND
RIVER
89
BEAR
SMITHFIELD
LAKETOWN
30
LOGAN
BEAR
17°
TRUE
MAGNETIC
1961 NORTH
0 1 2 3 4 5
SCALE IN MILES
RANDOLPH
HYRUM
89 U.S. HIGHWAY
30 STATE HIGHWAY

determine the mineralogy of sediments of different size fractions carried by the stream into Bear Lake.

This area was chosen because of the good accessibility throughout the area of study, the limited size but obvious importance of the drainage of North Eden Creek as a sediment source for Bear Lake, the presence of limestone, sandstone, the variable Wasatch Formation, and igneous rock within the drainage area, and a minimum disruption by man.

Location

The area studied lies in the north-central corner of Utah and the southeastern corner of Idaho, along the central portion of the east side of Bear Lake (Figure 1). Geographically it is located in the Middle Rocky Mountain Province of the Rocky Mountain System of Fenneman and Johnson (1946). The area is situated between lat 41°55'00" N. and 42°04'00" N. and between long. 111°05'00" W. and 111"16'30" W. The area of study covers parts of T. 14 N. and Rs. 6 and 7 E. in Utah and T. 16 S. and Rs. 44, 45, and 46 E. in Idaho.

A rectangular area that included the entire drainage area was chosen for mapping. As a result, boundaries of the area mapped extend beyond the drainage area in the northwestern and southwestern corners of the map. The maximum relief of the area is approximately 1770 feet, and varies with fluctuations of as much as 21 feet in the level of Bear Lake. The maximum altitude in the area is 7696 feet, the top of Black Mountain.

Most of the area is readily accessible on both graded and unimproved dirt roads that extend throughout the area, chiefly along streams (Plate 1). The roads on the Bear Lake Plateau are not maintained during the winter months, and therefore are essentially closed to vehicles whenever the area is covered with snow. These roads connect with U. S. Highway 89 in the north, and with State Highway 30 in the south, and extend eastward into Wyoming (Figure 1). Access from Logan is *via* Garden City and roads along the north and south ends of Bear Lake.

Climate and Vegetation

A mean annual precipitation of 10.93 inches has been recorded over a period of 30 years at Laketown, 11.6 miles south of North Eden Delta, and of 9.82 inches over a period of 30 years at the Lifton Pumping Station, Utah Power and Light, 12.8 miles northwest of the delta (U. S. Weather Bureau, 1964, 1965). The major portion of precipitation occurs in the form of snow during the winter. The average yearly temperature over a period of 30 years, at Laketown, has been 42.4 degrees F., and at the Lifton Pumping Station, 41.7 degrees F. The climate is classified as humid mesothermal with a dry summer (Blumenstock, 1966, p. 179). Vegetation consists mainly of sagebrush. Willows and a few cottonwood trees occur along streams in the larger canyons; on south-facing slopes in these same canyons several juniper trees also are present.

Field Methods

Field work was done during 12 weeks of the summer of 1968 and 3 weeks of the summer of 1969. A Brunton compass was used for strikes and dips of outcrops, whose positions were recorded on aerial photographs and also on topographic maps (U. S. Geological Survey, 60-minute quadrangles). Stratigraphic contacts and structures were plotted on aerial photographs and transferred in the office to hand templates constructed on mylar tracing film. Structural and stratigraphic interpretations necessitated numerous returns to some areas and close comparison with the straight-forward section along Indian Creek, 7.5 miles north of North Eden Delta. A section of Twin Creek Formation along structure section A-A' (Plate 2) was measured by the Jacob-staff technique, with a Brunton compass and Abney level.

Five days were spent selecting sites and acquiring samples of sediments along North Eden Creek and its tributaries. The samples were not taken from the modern stream channel because of sampling problems inherent in flowing streams; modern channel cliffs were used wherever possible. However, where it was necessary to dig trenches to obtain samples (Figure 3) the trenches were located as close to streams as feasible in locations that were obviously sites of recent fluvial deposition from evidence of the morphology at the site and from aerial photographs. Because the water table is close to the surface near streams, sites for trenches were picked as much as 3 feet above the stream and as much as 50 feet away.

Three samples were taken from channel cliffs within 1 to 4 feet of the stream, and a fourth from a quite recent entrenchment of approximately 15 feet through the fault escarpment on North Eden Delta. Heavy runoff and rainfall caused floods during the spring of 1969 which followed a man-made diversionary channel that became entrenched at the fault scarp. The trenches dug averaged 3 feet wide, 5 feet long, and 2 to 4.5 feet deep. Depths varied from locality to locality

Figure 2. View southwest across cuspate North Eden Delta. Steep fault scarp of Nugget Formation in foreground. Road along east side of delta follows crest of west-facing fault scarp 20 feet high. T. 14 N. and R. 6 E., Utah.

Figure 3. Pit dug for sample 11, just north of North Eden Creek. View East. T. 14 N. and R. 7 E., Utah.

because each trench was dug to the water table. The exposed section was observed, measured, and described in detail to determine whether it consisted of relatively recent stream deposits or whether it had a thick topsoil developed. Samples of approximately 600 grams were collected by scraping with a jacknife a vertical channel 2 inches wide and 1 inch deep down one side of each trench; the sediments fell into an opened entrenching shovel from which they were poured into sample bags that then were sealed and labeled. Particles larger than one inch were noted but not collected.

Laboratory Methods

The samples were split into portions of 40 to 50 grams with a Jones-type splitter (Krumbein and Pettijohn, 1938, p. 45). The sample then was placed in distilled water overnight to help break up clumps prior to wet sieving. Wet sieving was done with a 10-mesh (2 mm) and a 400-mesh (.037 mm) sieve. The samples then were oven dried at 60 to 80 degrees C. for 1 to 10 hours.

Weights of the samples were recorded to the nearest 0.01 gram on a Mettler Model P-1200 top-loading balance. The fraction between 10- and 400-mesh was dry-sieved through standard brass Tyler sieves on a ro-tap for fifteen minutes (Folk, 1965, p. 34). Sieve sizes of 35-, 60-, 120-, 230-, and 400-mesh (.50, .25, .125, .0625, and .037 mm) were used. The fraction caught on each sieve was weighed. Sediment that passed through the 400-mesh sieve was weighed and then added to the sediment acquired by wet sieving.

If the fraction smaller than 400-mesh weighed more than 10 grams (20 to 25 percent of the sample), it was separated by pipette analysis. Because of earlier drying this fraction was allowed to soak in distilled water and was stirred 4 times a day to disperse the particles prior to pipetting. Four withdrawals were made, one each for .0625, .031, .0039, and .00049 mm (coarse and medium silt and coarse and medium clay, respectively). Results are shown in Appendix A.

The minerals in the gravel size grade were identified by visual inspection. A Bausch and Lomb polarizing petrographic microscope was used to determine mineral content in the sand sizes. Each size grade was investigated individually after mounting on a glass slide with index oil of n = 1.540. A point count was made of the first 100 grains in each size grade. Results are shown in Appendix B.

Mineralogy of the silt and clay size grades was determined by X-ray diffraction on a Siemens Crystalloflex IV machine. A collimating slit of 1 mm and a receiving slit of 0.2 mm were used. A nickel filter was used to reduce the Cu $K\beta$ radiation produced by the copper-target X-ray diffraction tube. Diffraction tests were run for angles between 2° and 60° at a rate of 1° ($2\ \theta$) per minute. Identification and rough relative abundances were accomplished by comparison with A.S.T.M. data cards and with standards developed by Dr. Raymond L. Kerns, Jr.

PREVIOUS WORK

The earliest significant work in the area east of Bear Lake was by Peale (1879), who studied the Bear Lake Plateau during his geological surveys in the West. He described the Nugget, Twin Creek, and Wasatch Formations, although the first two were not then named. He recognized the major N-S-trending anticline in North Eden Canyon 2.3 miles east of Bear Lake (Plate 2).

Wheeler prepared topographic and land-classification maps of the area during his survey west of the 100th Meridian (Schmeckebier, 1904, p. 61). Gale and Richards (1910) attempted to reconcile the units defined by Boutwell (1907) in northeastern Utah and by Veatch (1907) in southwestern Wyoming. Gale and Richards subdivided the rocks of southeastern Idaho and adjacent parts of Utah and Wyoming into the following units: Twin Creek, Nugget, Ankareh, and Thaynes Formations (Figure 4).

Schultz and Richards (1913) made a geologic reconnaissance of southeastern Idaho, and Kirkham (1922, 1923) reported on the petroleum possibilities of southeastern Idaho.

Mansfield (1915) named the Higham, Deadman, and Wood Formations, all of which occur in the area of study. In 1920 he described Triassic and Jurassic strata in southeastern Idaho; subsequently (1927) he mapped the geology and mineral resources of southeastern Idaho. His map covers the north half of the area described herein and was used as an aid in field mapping north of the Utah-Idaho state line.

Richardson (1941) summarized the geology of the Randolph

Figure 4. Stratigraphic table showing some of the Triassic and Jurassic Formations of northern Utah, southeastern Idaho, and western Wyoming.

<table>
<tr><th>Age</th><th colspan="2">Veatch
SE Wyoming,
1907</th><th colspan="2">Gale and
Richards
SE Idaho, 1910</th><th>Boutwell
Park City dist.
Utah, 1912</th><th colspan="2">Mansfield
SE Idaho,
1920</th><th colspan="2">Kummel and
Zeni
SE Idaho, 1953</th><th colspan="2">This Report</th></tr>
<tr><td rowspan="2">Jurassic</td><td colspan="2">Twin Creek Formation</td><td colspan="2">Twin Creek Formation</td><td>Twin Creek Formation</td><td colspan="2">Twin Creek Formation</td><td colspan="2">Twin Creek Formation</td><td colspan="2">Twin Creek Formation</td></tr>
<tr><td rowspan="4">Nugget Forma-tion</td><td rowspan="4">Yellow sand-stone

Red sand-stone</td><td rowspan="4">Nugget Forma-tion</td><td rowspan="4">White sand-stone

Red sand-stone</td><td>Nugget Formation</td><td colspan="2">Nugget Formation</td><td colspan="2">Nugget Formation</td><td colspan="2">Nugget Formation</td></tr>
<tr><td rowspan="3">Triassic(?)</td><td rowspan="4">Ankareh Formation</td><td colspan="2">Wood Formation</td><td colspan="2">Wood Formation</td><td colspan="2">Wood Formation</td></tr>
<tr><td colspan="2">Deadman Formation</td><td colspan="2">Deadman Formation</td><td colspan="2">Deadman Formation</td></tr>
<tr><td colspan="2">Higham Formation</td><td colspan="2">Higham Formation</td><td colspan="2">Higham Formation</td></tr>
<tr><td rowspan="6">Lower Triassic</td><td colspan="2" rowspan="6">Thaynes Formation</td><td colspan="2" rowspan="3">Ankareh Formation</td><td colspan="2">Timothy Formation</td><td rowspan="6">Thaynes Forma-tion</td><td>Timothy Member</td><td rowspan="6">Thaynes Forma-tion</td><td>Timothy Member</td></tr>
<tr><td rowspan="5">Thaynes Formation</td><td rowspan="5">Thaynes Group</td><td>Portneuf Formation</td><td>Upper Portneuf Member</td><td rowspan="5">Portneuf Member

Not exposed</td></tr>
<tr><td>Fort Hall Formation</td><td>Lanes Tongue of Ankareh</td></tr>
<tr><td colspan="2" rowspan="3">Thaynes Formation</td><td rowspan="3">Ross Fork Formation</td><td>Upper calcareous siltstone</td></tr>
<tr><td>Middle shale and lime-stone</td></tr>
<tr><td>Lower shale and lime-stone</td></tr>
</table>

Quadrangle, which covers the southern half of the area described herein. His map was an aid south of the Utah-Idaho state line in the present study.

Kummel (1943, 1953, 1954) studied the Triassic formations of Idaho. He stated that the lower members of the Thaynes Formation lose their identity southward in Idaho, so that the higher Portneuf and Timothy members predominate in Bear Lake Valley (Kummel, 1954, p. 175).

Imlay (1953) described in detail geologic sections of the Twin Creek Formation measured in northern Utah, southeastern Idaho, and western Wyoming. These section measurements and descriptions aided in the measurement and identification of members of the Twin Creek Formation in the area of study.

Hardy and Williams (1953) summarized the geology in the area studied, and apparently were the first to recognize the N-S-trending thrust fault near its western margin.

Williams, Willard, and Parker (1960, 1962) studied the Pleistocene and Holocene geomorphology of Bear Lake Valley. They concluded that the west-facing scarp on North Eden Delta is a fault scarp rather than an abandoned wave-cut cliff. They recognized the presence of the Lifton shoreline at 5929 feet on North Eden Delta. The Lifton level is present almost continuously around the lake. The Willis Ranch and Garden City levels of the lake occur along the fault scarp. However, due to movement along the fault these levels cannot be distinguished. Terraces occur at even higher levels where North Eden Creek has cut through older deltaic sediments or an old alluvial fan.

Davidson (1969) pointed out an uncertainty about the origin of calcite and dolomite in the silt- and clay-sized sediments of

Bear Lake. His work prompted the present study of drainage into Bear Lake to determine whether these minerals have a detrital origin.

GEOLOGIC HISTORY

The area studied is located near the inner edge of the Paleozoic Miogeosyncline (Bissel, 1962, p. 192-193), and during that time received thick deposits of carbonates. Tectonic activity increased during the Mesozoic Era, when the area was intermittently above and below sea level, and received deposits of shoreline clastics, terrestrial sediments, and marine carbonates and fine clastics. Folding and eastward thrust faulting during the Laramide Orogeny was followed by long-continued erosional stripping, block (gravity) faulting, and deposition of fluvial and lacustrine facies of the Wasatch Formation. Activity along gravity faults that bound the east and west sides of Bear Lake formed the graben that is now Bear Lake Valley. A fresh, west-facing scarp, approximately 20 feet high, trends N-S across the eastern side of North Eden Delta, evidence of recent activity on the gravity fault bounding the eastern side of Bear Lake. Streams have eroded broad and deep canyons as they flowed into the valley from rising adjacent highlands of the Bear Lake Plateau and Bear River Range.

During previous episodes of wetter climatic conditions, possibly times of glacial advances, lakes filled much of Bear Lake Valley. Williams, Willard, and Parker (1962, p. 28-30) reported radiocarbon dates of approximately 8,000 years B. P. from shells found in the Lifton and the Willis Ranch shorelines. At times of expanded lakes and higher stream runoffs, deltas formed at the mouths of major streams draining into Bear Lake, including North Eden Delta (Figure 2). As the lake receded from its most recent maximum, three distinct shorelines were formed and successively abandoned. From highest to lowest, they are the Willis Ranch, Garden City, and Lifton levels and stand 25, 15, and 6 feet, respectively, above the present average lake level (Williams, Willard, and Parker, 1962, p. 28-30).

MORPHOLOGY

General Statement

The Bear Lake Plateau dominates the east side of Bear Lake. South of North Eden Delta, a fault scarp formed of Jurassic sandstone rises steeply from the lake level, at approximately 5923 feet, to above 7000 feet. North of North Eden Delta, older and less resistant beds occur along the fault bounding the valley so that the topography rises more gradually and relief is more subdued. Eastward the topography flattens to form the Bear Lake Plateau which extends eastward for approximately 11 miles to the valley of the Bear River. Although streams have cut through the fault scarp and dissected the plateau in several places, the over-all flatness of the plateau remains through much of the area. Relief in the area is greatest along the fault scarp and immediately eastward, along the canyons of North and South Eden Creeks.

Black Mountain, although the highest point in the area at 7696 feet, has a low relief because it rises from the high-standing plateau surface (Figure 5) that surrounds Black Mountain at an altitude of approximately 7000 feet. Richardson (1941, p. 35) believed that the basalt cap of Black Mountain is an erosional remnant of a flow of igneous rock that formerly covered a much more extensive area and that the location of the vent was not known. From personal investigation on the site and studies of aerial photographs, Black Mountain appears to be the north rim of the former crater that encircled the volcanic vent,

Figure 5. View south across North Eden Canyon to Black Mountain. Remnants of Bear Lake Plateau in foreground and also flanking Black Mountain. T. 14 N. and R. 6 E., Utah.

Figure 6. View north into crater remnant at Black Mountain. Note lobate basalt flow at base of old crater wall. T. 14 N. and R. 6 E., Utah.

from which an obvious basalt flow emerged (Figure 6).

Spurs, locally with bedrock cores, project into the valley on the downstream sides of tributaries of North Eden Creek (Figure 7). These spurs have flat tops that slope toward the stream; the upstream side is linear and usually perpendicular to the main stream. These spurs appear to grade downstream to high-standing terraces located at the mouth of North Eden Canyon and may be portions left after erosion of an older valley profile. A valley fill in the tributary directly north of sample station 4 also appears to be graded to the same level. In areas lacking soil cover, distinct layering within the spurs is visible. These remnants possibly formed when the base level of the stream was higher, quite likely prior to the most recent gravity faulting along the east side of Bear Lake. Distinct layering similar to that in the spurs is also visible in other alluvial deposits along North Eden Creek (Figure 8).

Drainage

North Eden Creek, shown by locations of samples 4, 5, and 6 (downstream, main channel) and 7, 10, 11, and 13 (upstream, main channel) on Plate 1, flows westward from the Bear Lake Plateau into Bear Lake. Samples taken from tributaries are identified by station numbers 8, 9, 12, and 14. The average gradient of the stream is 70 feet per mile. The gradient of the main stream above station 12 is approximately 94 feet per mile; between stations 4 and 11 it is approximately 64 feet per mile. The gradient of the tributary between stations 8 and 14 is approximately 77 feet per mile, and that of the tributary above station 9 is approximately 129 feet per mile. The

Figure 7. View west (downstream) from north side of upper reservoir. Note spur extending into North Eden Canyon on downstream side of mouth of tributary canyon. T. 14 N. and R. 6 E., Utah.

Figure 8. Layering in artificial cut in alluvium on north side of upper reservoir, North Eden Canyon. T. 14 N. and R. 6 E., Utah.

headwaters of North Eden Creek form a widely distributed dendritic pattern in the flat-lying Wasatch Formation. Between stations 7 and 11 meanders are visible in the abandoned parts of the floodplain. The floodplain varies in width from a few hundred feet in the lower portion of the stream to almost one mile locally in the upper portion. In the downstream area, below station 7, major tributaries form strike valleys and follow the N-S structural and lithologic grain as subsequent streams; these tributaries are approximately 0.4 mile apart. In the upstream area, station 7 and above, where the stream meanders, the tributaries are approximately 0.8 mile apart. There are no major tributaries below station 4 (Plate 1). Each major tributary tends to drain only one or two stratigraphic units through most of its extent. Minor tributaries are consequent in the Wasatch Formation south of station 14. The tributaries above station 12 are mostly consequent, whereas the majority of the tributaries in the lower portion of the stream are subsequent along the Sheep Creek Anticline.

North Eden Creek is a fourth-order stream (Leopold, Wolman, and Miller, 1964, p. 134). Its first- and second-order tributaries have no meanders, even in the Wasatch Formation. Its greatest length is approximately 12.5 miles, and the average of its third-order tributaries is approximately 3.3 miles. Lower-order streams, of course, are successively shorter.

Two earth-fill dams were constructed on North Eden Creek in the first half of this century, for flood control and for storage for summer irrigation. Subsequently, water from the creek has been diverted entirely for irrigation of North Eden Delta.

STRATIGRAPHY

General Statement

Both consolidated and unconsolidated materials occur in the area studied. Unconsolidated sediments are of Quaternary age and consist of alluvium, colluvium, lake deposits, and landslide debris. The consolidated rocks are of Triassic, Jurassic, and Tertiary age (Figure 4). Sandstone, limestone, and conglomerate comprise the sedimentary rocks present. A basalt of Tertiary age forms Black Mountain, the highest point in the area. Because each stratigraphic unit is characterized by distinctive and nearly uniform lithology throughout its extent and thickness, a geologic map very closely approximates a lithologic map and has the added advantage of showing geologic structures. Therefore, a geologic map was prepared as a preferable substitute for a lithologic map (Plate 1). Because of their thinness and occurrence outside the drainage area of North Eden Creek, the Higham, Deadman, and Wood Formations are mapped together as a single unit. These stratigraphic units are discussed below in sequence from oldest to youngest.

Triassic

Thaynes Formation

The Thaynes Formation of Lower Triassic age is the oldest formation in the study area. It was named by Boutwell (1907) for exposures in Thaynes Canyon in the Park City district, Utah.

Kummel (1954) recognized seven members in the Thaynes Formation in southeastern Idaho; however, only the topmost two, the Portneuf and the Timothy Members, are present in the area mapped. Kummel, 1954, p. 175) described the Portneuf Member as a massive, gray to blue, crystalline limestone and the Timothy Member as a red siltstone, shale, and sandstone. He further stated (1953, p. 52) that the Thaynes Formation is of marine origin and is the time equivalent of the Moenkopi Formation of the eastern Uinta Mountains, Utah, and the Chugwater Formation of central Wyoming. Mansfield (1927, p. 82) reported a thickness of 2850 feet for the Thaynes Formation in southeastern Idaho.

The red siltstone and shale of the Timothy Member were not found in the area studied; only the sandstone of the Timothy Member is present, overlying the distinctive gray to blue limestone of the Portneuf Member. The Portneuf Member forms a low ridge (Plate 1) along the eastern side of Bear Lake north of North Eden Delta. Beds are overturned; they dip steeply westward and strike N 5° E in the west limb of the asymmetrical Indian Creek Syncline. The Timothy Member is also overturned. It forms a low swale also trending N 5° E, just east of the Portneuf Member. The Portneuf and Timothy Members do not contribute sediments to North Eden Creek, although small creeks that drain them do empty directly into Bear Lake. Farther north in Indian Creek, the Thaynes Formation conformably overlies the Triassic Woodside Formation.

Higham Formation

The Higham Formation is of Upper Triassic (?) age. It was named by Mansfield (1915) for Higham Peak on the Fort Hall Indian Reservation in Idaho. The Higham is the equivalent of the Shinarump Formation of central Utah and is of continental origin with a probable source area to the west (Kummel, 1953, p. 53). Mansfield described the unit as a white to pinkish, coarse-grained, gritty or conglomeratic sandstone derived from early Paleozoic or older quartzites (1927, p. 95).

The Higham Formation is 200 feet thick just north of the study area in southeastern Idaho (Mansfield, 1927, p. 82), and crops out in the study area just east of the Thaynes Formation in the west limb of the asymmetrical Indian Creek Syncline (Plate 1). It rests disconformably on the Timothy Member of the Thaynes Formation in southeastern Idaho (Mansfield, 1920b, p. 29). The formation forms a low swale that strikes N 10° E; and, like the Thaynes, this unit is cut out in the south by the gravity fault bounding the east side of the lake. Although the Higham Formation does not contribute sediments to North Eden Creek, intermittent streams flow through the formation into Bear Lake. In the study area the Higham Formation is a white to pinkish, coarse-grained, quartzose sandstone with calcite cement.

Deadman Formation

The Deadman Formation is of Upper Triassic (?) age. It was first described by Mansfield (1915) from an outcrop on Deadman Creek in the northeastern part of the Fort Hall Indian Reservation in Idaho. Later measurements showed it to be approximately 200 feet thick in that area (Mansfield, 1927, p. 82). Mansfield described it as a dense, purplish gray limestone of almost lithographic quality, with subordinate amounts of gray and greenish chert (1916, p. 41).

North of North Eden Delta the Deadman Formation crops out east of Bear Lake; it overlies the Higham Formation conformably and forms part of the same swale. It underlies the Wood Formation (Plate 1). It trends N 10° E and also is cut off in the south by the gravity fault bounding the east side of Bear Lake. The Deadman Formation does not contribute any sediments to North Eden Creek, but it is drained by intermittent streams that flow into Bear Lake.

In the area of study, the formation consists of a unit of dark gray limestones sandwiched between units of white limestones. These beds dip steeply eastward and are not overturned. The Deadman Formation is of continental origin and is considered by the present author to be the time equivalent of part of the Chinle Formation of southern Utah.

Wood Formation

The Wood Formation is of Upper Triassic (?) age. It was named by Mansfield (1915) for an outcrop on Wood Creek in the Fort Hall Indian Reservation in Idaho and is thought by the present author to be the time equivalent of part of the Chinle Formation of southern Utah. In the area studied, it consists of a bright red shale that weathers readily into red soil and that commonly forms valleys. It overlies conformably the Deadman Formation, and gradationally underlies the Nugget Formation (Mansfield, 1927, p. 82). The Wood Formation is approximately 150 feet thick in southeastern Idaho (Mansfield, 1927, p. 82) and is likely of continental origin (Kummel, 1953, p. 53). It trends N 10° E and crops out north of North Eden Delta (Plate 1) where it dips steeply eastward in the west limb of the asymmetrical Indian Creek Syncline.

Jurassic

Nugget Formation

The Nugget Formation of Lower Jurassic age forms the steep, west-facing escarpment along the eastern side of Bear Lake just north and to the south of North Eden Delta. Here it forms a band nearly 0.75 mile wide that trends N 5° E and extends the entire length of the area mapped. It also crops out in a band approximately 1 to 2 miles wide that trends N 10° E from the north edge of the area studied to a point just south of North Eden Canyon, along the crest of Sheep Creek Anticline (Plate 1). Small outcrops occur along South Eden Anticline in South Eden Canyon. It is best exposed in canyons of east-west streams and locally on top of the Bear Lake Plateau (Plate 1). The Nugget Formation is a major source of quartz for North Eden Creek which flows across the formation. The formation was named by Veatch (1907) for an exposure at Nugget Station in southwestern Wyoming.

The Nugget Formation consists of two members, a lower member of thin-bedded sandstones that are light yellow on fresh exposures and dark brown where weathered and an upper member of red sandstones containing numerous joints (Figure 9), cross-beds, and oscillation ripple marks.

Gale and Richards (1910, p. 470) reported a thickness of 1900 feet for the Nugget Formation in southeastern Idaho and in adjacent parts of Utah and Wyoming. Baker, Dane, and Reeside (1936, p. 5) concluded that it is the direct equivalent of the Navajo Formation of southern Utah.

Twin Creek Formation

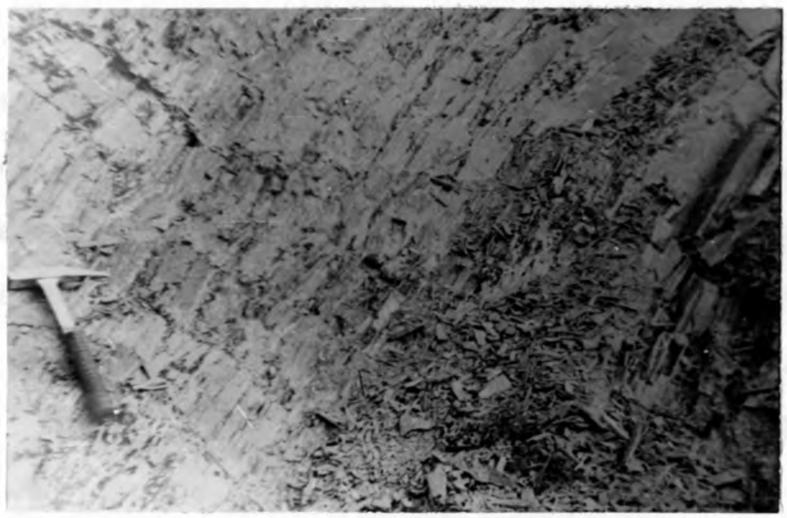
The Twin Creek Formation of Upper Jurassic age was named by Veatch (1907) at Twin Creek, Wyoming. He described a marine fauna (1907, p. 56) from this unit. The Twin Creek Formation is considered the direct equivalent of the Carmel Formation of southern Utah (Baker, Dane, and Reeside, 1936, p. 6).

Imlay (1953) identified seven members in the Twin Creek Formation in Indian Creek, 7.5 miles north of North Eden Delta. All are present in the area of study. From youngest to oldest they are:

	Thickness in feet
Member G: sandstone and sandy limestone, thin-bedded pinkish, weathers dull pinkish gray	71
Member F: soft limestone that weathers into splinters thin-bedded, medium gray, weathers light gray (Figure 10)	1500+
Member E: limestone, thin- to thick-bedded near base, resistant in the middle, and oölitic to coquinoid at top, medium gray	299
Member D: brownish red siltstone and light yellowish gray, thin-bedded, shaly limestone	90
Member C: limestone, shaly, soft, thin-bedded, light gray	114
Member B: limestone, light gray to white; low cliff forms at top of unit	245
Member A: brownish red siltstone and brecciated gray limestone	196

Figure 9. View of Nugget Formation showing jointing and crossbedding. T. 16 S. and R. 44 E., Idaho.

Figure 10. Splintery weathering characteristic of Member F of Twin Creek Formation. T. 14 N. and R. 7 E., Utah.



Total thickness 2515+ ft

(Measurements of Units F and G, in Pruess Creek, from Imlay, 1953, p. 60. Other units measured by McClurg and Oaks in North Eden Canyon on east flank of Sheep Creek Anticline.)

Richardson (1941, p. 30) found the following marine fossils in the Twin Creek Formation in the study area:

Ostrea strigilecula White

Pentacrinus asteriscus Meek and Hayden.

North of North Eden Delta (Plate 1) the Twin Creek Formation occurs in the limbs of Sheep Creek Anticline. On the west side of that structure, it forms the tightly folded Indian Creek Syncline and is bounded in the west by the Bear Lake Thrust (Plate 2). South of North Eden Canyon, the formation apparently closes around the south-plunging nose of Sheep Creek Anticline, but there it is covered in many places by the Wasatch Formation so that its precise extent is uncertain. Because it is covered by the flat-lying Wasatch Formation, the eastward extent of the Twin Creek Formation also is uncertain.

Because the main stream and its tributaries traverse the Twin Creek Formation through much of their extents, the unit is probably a major source of calcite for North Eden Creek. Units C and F of the Twin Creek Formation probably supply silt- and clay-sized calcite to North Eden Creek. The Twin Creek conformably overlies the Nugget Formation. Wherever the flat-lying Wasatch occurs as a cap for the Twin Creek, it is in angular unconformity.

Tertiary

Wasatch Formation

The Wasatch Formation of Paleocene and early Eocene age was named by Hayden in 1869 for exposures in Echo and Weber Canyons in the Wasatch Mountains of Utah. Richardson (1941, p. 32-34) reported a maximum thickness of 1000 feet in the Bear River Range. It consists chiefly of unconsolidated to partly consolidated channel conglomerates and sandstones and floodplain siltstone, predominantly red in color, with calcite cement. The beds are nearly horizontal. The greatest dip measured in the study area was 6°, which could be depositional rather than structural. Pebbles and cobbles of the conglomerate consist mainly of quartzites, probably derived from a Paleozoic or Precambrian source, perhaps the Mutual, Brigham, or Swan Peak Formations, or the Uinta Mountain Group. Some chert nodules also are present in the conglomerate. The Wasatch Formation contributes both quartz and calcite to the drainage basin of North Eden Creek. It may also be a source of feldspars, although none was found in a carefully analysed sample of Wasatch Formation from the study area.

The Wasatch Formation occurs as a flat-lying cap that forms the surface of undissected portions of the Bear Lake Plateau (Plate 1). It is angularly discordant with the underlying Nugget and Twin Creek Formations. It covers most of the eastern and southern (headwater) portions of the drainage area of North Eden Creek; it occurs as isolated, high-standing remnants in the more dissected area north of North Eden Canyon; and it occupies much of the low area along the axis of Sheep Creek Anticline north of North Eden Canyon. The Wasatch

Formation is the time equivalent of the Fort Union Formation of Wyoming (Jones, Picard, and Wyeth, 1954, p. 2221).

A local facies was named the Cowley Canyon Member by Williams (1948, p. 1121). The type locality for this member is Cowley Canyon of the Right Fork of Logan Canyon, Utah. It is well exposed (Plate 1) around Black Mountain and the upper portions of knolls in the eroded central portion of the Sheep Creek Anticline. The maximum measured thickness of the Cowley Canyon Member of the Wasatch Formation is approximately 20 feet at the exposure on the southern end of Black Mountain. It is light gray to cream colored, oölitic, pisolitic, or algal limestone in most exposures. Elsewhere, it also contains stromatolitic limestones. The unit apparently originated in local lacustrine environments within the fluvial terrain of Wasatch deposition.

Basalt

The basalt of Black Mountain (Plate 1) postdates the Wasatch Formation and thus is of Middle Eocene age or younger. Its well preserved but partly dissected morphology suggests a late Tertiary or early Quaternary age. However, it is sufficiently dissected and weathered that a late Quaternary age seems unlikely. It is an alkaline olivine basalt and perhaps is a source of feldspars in the lower part of North Eden Creek. Some tributary headwaters reach within 2 miles of the exposed basalt. Although within the drainage of North Eden Canyon, Black Mountain contributes very little to the mineralogy of the stream. The main constituents of the basalt, olivine, labradorite, and augite were identified by X-ray diffraction. Percentages were not calculated because standards were not available for comparison. However, neither augite nor olivine was identified within sediments of the stream.

Quaternary

Lakeshore deposits

The beaches along the shore of Bear Lake, including those along North and South Eden Deltas (Plate 1), consist of gravel, sand, silt, and shells. These deposits were derived from sediments carried into the lake by streams, by mass movement of sediments from the ridges next to the lake, by wave transport of sediments from the adjacent lake bottom, and by organic and chemical precipitation.

Sediment samples from the beach at North Eden Delta range from angular with low sphericity to rounded with high sphericity (Powers, 1953, p. 118). They are extremely poorly sorted and contain 15 to 20 percent broken and abraded shells.

Alluvium

Unconsolidated deposits of alluvial gravel, sand, silt, and clay occur along the valley bottom of North Eden Canyon and downstream portions of the major tributaries (Plate 1). These deposits are derived from the formations previously described, and are subjected to further chemical and mechanical weathering during transportation. Spurs that extend out into North Eden Canyon (Figure 7) may be due to floods that carried material out of the tributary canyons periodically. They appear to be abandoned remnants of an older valley profile. Distinct layers of varying grain sizes are exposed near the upper reservoir and appear related to marked changes in stream energy (Figure 8). Whether such changes resulted from climatic variations during the Pleistocene or from intermittent spectacular floods is uncertain.

Colluvium

Loose debris formed by weathering of various formations has moved downhill in relatively steep areas to form aprons of colluvial deposits in many parts of the study area (Plate 2). Colluvium commonly flanks alluvial deposits and also masks contacts between older stratigraphic units locally. Only larger colluvial areas were mapped. In many places, the contact between colluvium and its parent material proved quite difficult to locate precisely in the field, so that subtle slope changes and tonal changes on aerial photographs commonly were used.

Landslide debris

In the northwestern part of the area mapped, outside the drainage of North Eden Creek, an ancient debris slide moved down from the Wasatch Formation across the Twin Creek Formation and stopped a short distance past the contact between the Twin Creek and Nugget Formations (Plate 1). The head scarp, in the Wasatch Formation, and debris within the slide and in the terminal mound all have been moderately eroded.

STRUCTURE

The major folds and thrust faults in the area were formed during the Laramide Orogeny. Indian Creek Syncline (Figure 11) was named by Mansfield (1927). Its axis occurs approximately 1 mile east of Bear Lake in the northwestern portion of the study area (Plate 2). Its axis trends N 10° E and nearly parallels the Bear Lake Thrust Fault, only 0.2 mile westward. This syncline is tightly folded, and the youngest unit in its center is the Jurassic Twin Creek Formation. A probable southward extension of the syncline is observed on the south side of North Eden Canyon approximately 1 mile east of North Eden Delta.

Sheep Creek Anticline was named by Mansfield (1927). Its axis occurs 2.3 miles east of North Eden Delta (Plate 2). Its axis trends approximately N 20° E and can be traced for 30 miles north of the area studied. In the northern part of the area, the exact location of the axis is obscured by the Wasatch Formation; the structure appears to die out in a south-plunging nose just south of North Eden Canyon.

South Eden Anticline is named here. Its axis occurs approximately 2.5 miles east of South Eden Delta and trends approximately N 15° E. This anticline may or may not be the southward extension of Sheep Creek Anticline. Because the two anticlines are approximately aligned, involve the same rock units, and exhibit an igneous extrusion along the projected connection of the axes, the two structures are thought to be continuations of the same structure, separated by a minor structural sag.

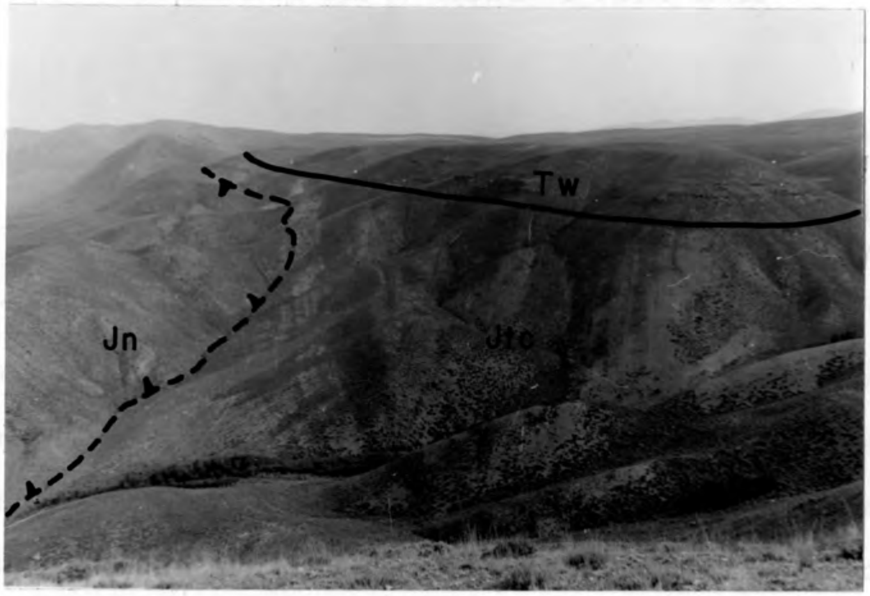
Three minor folds, the West Nebeker Ranch Anticline, the East Nebeker Ranch Anticline, and the Nebeker Ranch Syncline, are named here. Their axes occur approximately 0.5, 1.5, and 1 mile east of South Eden Delta, respectively. These folds apparently resulted from compression caused when an upper thrust plate (Bear Lake Thrust Fault) was pushed eastward over a lower thrust plate (South Eden Thrust Fault). These folds trend approximately N 35° E.

The Bear Lake Thrust Fault is named here and trends approximately N 10° E through the area of study. Its trace is located approximately 0.8 mile east of, and almost parallel to, Bear Lake. This fault has created some rather unusual relationships between the Nugget and Twin Creek Formations (Plate 1). The lower thrust fault, here named South Eden Thrust Fault, intersects the surface approximately 1.5 miles east of South Eden Delta.

Normal (gravity) faulting formed the Bear Lake graben. The fault scarp bounding the east side of Bear Lake stands 20 feet high and is clearly visible on both North and South Eden Deltas. This fault, which trends N 5° E, is the cause of the steep escarpment between North and South Eden Canyons (Figure 12). Small fault scarplets are visible across the beaches on the lake in the study area but were not mapped due to lack of continuity.

Figure 11. View north from drainage divide north of North Eden Canyon. Tightly folded Indian Creek Syncline (Jurassic Twin Creek Formation in center) is bounded in the west by Bear Lake Thrust Fault and Jurassic Nugget Formation. Angular discordance of flay-lying Tertiary Wasatch Formation is exhibited in upper right. T. 16 S. and R. 45 E., Idaho.

Figure 12. View south toward North Eden Delta along steep fault scarp in Nugget Formation. T. 14 N. and R. 6 E., Utah. (Photograph by Robert Q. Oaks, Jr.)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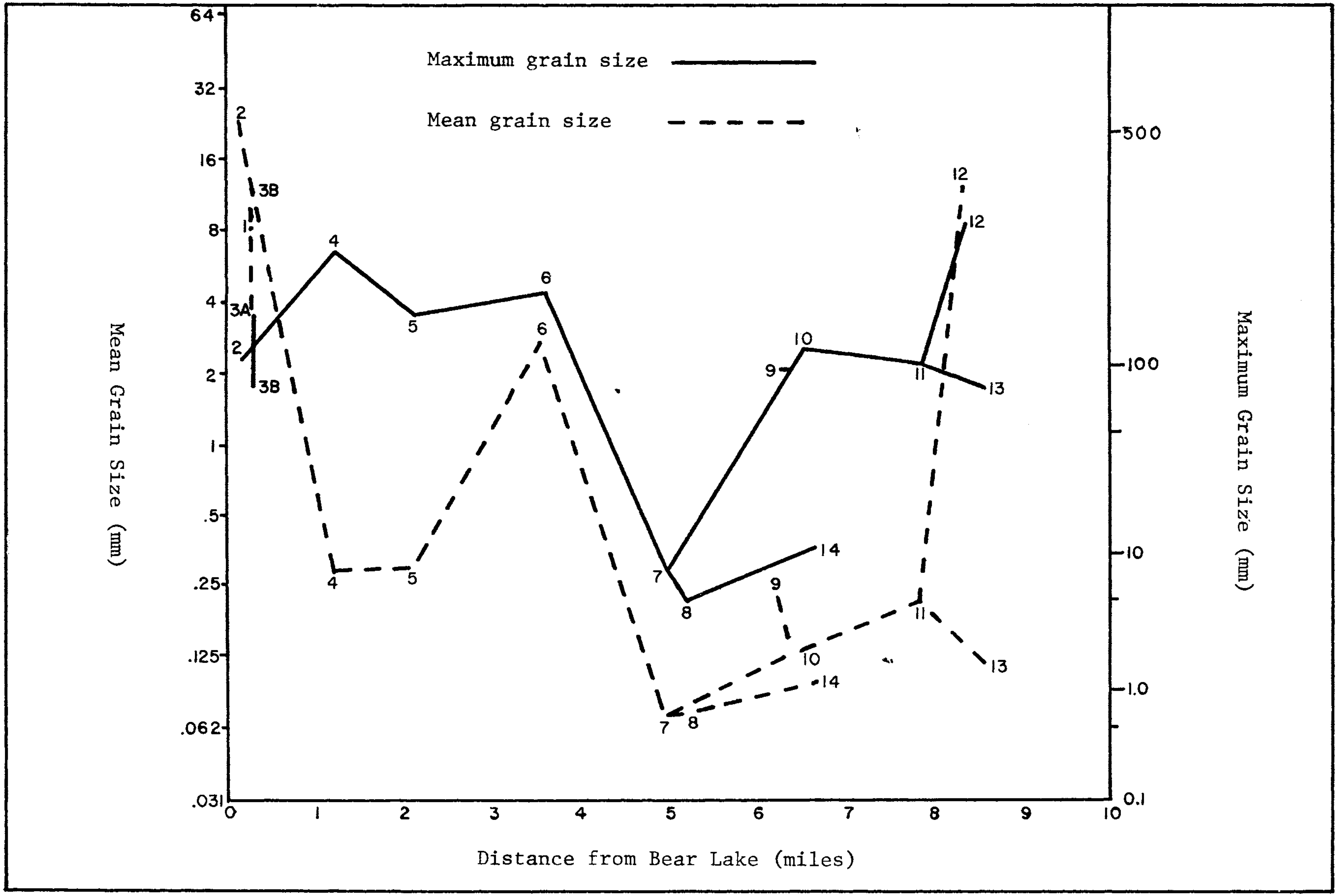
CHARACTERISTICS OF SEDIMENTS TRANSPORTED BY NORTH EDEN CREEK

Downstream Changes in Grain Size

Fourteen sample locations were selected from topographic maps and aerial photographs to determine contributions of major tributaries to mineralogy, to characterize downstream alterations in mineralogy and changes in grain size, and to assess any modifications that occur to the sediment after it reaches the lake. Sample locations are shown in Plate 1. Numbers increase from 1, 2, and 3 on the delta to 12, 13, and 14 at the points of joinup of the most distal tributaries. Particle-size distributions were plotted for 15 samples taken from these 14 stations (two samples were collected from obviously different beds at station 3; see Appendix 1).

Along North Eden Creek itself (samples 4, 5, 6, 7, 10, 11, and 13), both mean and maximum grain sizes vary in an unsystematic manner (Figure 13), in contrast with observations by other workers on many other streams that grain size generally exhibits over-all downstream decreases in grain size (Leopold, Wolman, and Miller, 1964, p. 191). However, the main stream cuts perpendicularly across several contrasting lithologies; its headwaters lie in the flat-lying, relatively weak, and easily eroded Wasatch Formation; whereas its downstream portions traverse steeply dipping limestones of the Twin Creek Formation and coarser-grained sandstones of the Nugget Formation that break out along joints into large blocks.

Figure 13. Maximum and mean grain sizes of sediment samples from North Eden Delta and from the drainage of North Eden Creek. Numbers refer to sample stations shown in Plate 1.



Maximum grain size
Mean grain size
Mean Grain Size (mm)
Maximum Grain Size (mm)
Distance from Bear Lake (miles)
64
32
16
8
4
2
1
.5
.25
.125
.062
.031
500
100
10
1.0
0.1
0
1
2
3
4
5
6
7
8
9
10

At stations 4, 5, and 6 mass-wasted debris of the Nugget Formation is available to the stream. At stations 4 and 6, samples were taken just downstream from tributaries; at station 5, just upstream. At all three stations there is a sharp increase in the maximum grain size, from 7.6 in sample 7 to 177.8, 152.4, and 254.0 mm for samples 6, 5, and 4 respectively (Figure 13). The mean grain size increases from 0.075 in sample 7 to 3.0 mm in sample 6, but then drops to intermediate values of 0.30 and 0.28 mm in samples 5 and 4 respectively.

In the headwaters draining the Wasatch and Twin Creek Formations, the tributary samples (8, 9, 12, and 14) have a mean particle size of .085, 0.28, 12.0, and 0.1 mm respectively, with a maximum grain size of 5.1, 101.6, 304.8, and 10.2 mm, and a mode of coarse silt, silt, gravel and coarse silt, respectively. The main stream samples (7, 10, 11, and 13) have a mean grain size of 0.075, 0.15, 0.21, and 0.125 mm respectively, and a maximum grain size of 7.6, 114.3, 101.6, and 76.2 mm and a mode of coarse silt, silt, coarse silt, and coarse silt respectively (Appendix 1).

In North Eden Canyon where the stream is cross-axial across structures and drains the Nugget, Twin Creek, and Wasatch Formations, sample 5, just above a major tributary, has a mean particle size of 0.3 mm, a maximum grain size of 152.4 mm, a major mode in the fine sand range, and a secondary mode in the coarse silt range. Samples 4 and 6, just below major tributaries, have a mean grain size of 0.28 and 3.0 mm, a maximum grain size of 254 and 179 mm, and a mode of silt with a secondary mode of gravel, and a mode of gravel, respectively. Sample 5, above a tributary, differs from samples 4 and 6, below tributaries, in having more fines and a smaller maximum grain size. Sample 6 is better sorted than either 4 or 5.

Samples 1 and 3B are very poorly sorted with values of 2.2 ϕ and 2.5 ϕ respectively; whereas samples 2 and 3A are extremely poorly sorted with values of 4.6 ϕ and 4.3 ϕ respectively (Folk, 1965, p. 46). By comparing the other samples (4-14) with samples 1, 2, 3A, and 3B, it was determined that all samples are poorly sorted. Although poor sorting is a common condition for stream-channel deposits, its occurrence here probably is chiefly the result of the sampling technique.

Stations 1, 2, 3A, and 3B, located on North Eden Delta, have a mean grain size of 8, 24, 3.5, and 12 mm respectively, with a maximum grain size for samples 2, 3A, and 3B of 101.6, 76, and 63 mm respectively, and a mode in the gravel range.

The particle size in the stream would most likely decrease downstream if there were no tributaries adding coarse-grained sediments to the stream. The mean particle size of the main stream in the narrow confines of North Eden Canyon increases downstream, as does the maximum grain size. This is probably due to the addition by mass-wasting of the Nugget Formation next to the stream and to the short distances the tributaries carry their sediments.

Mineral Abundances in Different Size Fractions

Percentages of minerals (Appendix 2) were determined for each of the coarse size fractions in the 15 samples. Percentages of minerals in the silt and clay sizes were not determined because there were no standards readily available for comparison with the X-ray diffraction patterns.

In the gravel sizes, quartzite and chert predominate in the headwater areas draining the Wasatch Formation. These probably were derived initially from Paleozoic and Precambrian terranes and are now being recycled. Farther downstream sandstone chunks are added to the gravel fraction where tributaries drain the Nugget Formations.

In the sand sizes, quartz is the dominant mineral (> 50 percent), although calcite is also an important constituent (15 to 50 percent) in all samples except 3A, 3B, 5, 12, and 13, in which calcite is a minor constituent (1 to 15 percent). In samples 4 and 14 very small amounts of sand-sized dolomite are present.

In the silt range, the dominant mineral again is quartz (Appendix 1). The major difference here is the great increase in the amounts of the clay minerals, illite, kaolinite, and montmorillonite. Calcite also increases in importance in samples 1, 3A, 3B, and 5; in sample 3B it is even the dominant mineral in the silt range. Dolomite likewise increases in importance in the silt sizes in samples 1, 4, and 11.

Except for sample 5, quartz is absent in the coarse clay size (.0039-.00049 mm). Calcite decreases sharply in quantity also, but still is present in coarse clay of samples 9, 11, and 14. Kaolinite is the dominant mineral in the coarse clay size, and illite also is abundant but not so important as kaolinite. Montmorillonite is a minor constituent, occurring only in sample 4. In the fine clay size (< .00049 mm) only kaolinite and amorphous material are present.

Mineral Constituents

Quartz occurs in all size grades except the fraction

< .00049 mm; its ubiquitous occurrence probably is due to its high resistance to mechanical weathering. Quartz grains in the samples have both undulant and straight extinction, which indicates that the quartz was derived from more than one source (Folk, 1965, p. 69). Inclusions were not observed in quartz grains, but overgrowths of calcite were common. The quartz grains are subangular, subrounded and rounded, and all have a high sphericity (Powers, 1953, p. 118). Quartz occurs in all the sedimentary formations in the drainage area and is the dominant mineral in the sand and gravel sizes and in the silt sizes in all but two of the samples (1 and 3).

Calcite also occurs in all size grades except the fraction < .00049 mm. Even on North Eden Delta it is an important mineral, occurring most commonly in the sand and gravel sizes as a secondary coating on quartz grains. It also is present in the sand and gravel sizes as aggregates of silt- and clay-sized particles.

Feldspar is present only in the silt range and only in samples 2, 3A, 4, 5, 6, 7, and 13. X-ray analysis of a sample of Wasatch Formation showed an absence of feldspar in that sample. Therefore, it is tentatively concluded that much of the feldspar in downstream samples could be derived from basalt of Black Mountain, although that in samples 7 and 13 most likely was derived from local arkosic beds within the Wasatch Formation.

Kaolinite is the dominant clay mineral and is a common product of terrestrial weathering (Grim, 1968, p. 537). Illite is the next most abundant clay mineral. Like kaolinite, it occurs in a majority of the samples. The local source of illite is uncertain, although it could be derived locally from the Wasatch Formation. Montmorillonite, present only in sample 4, possibly results from alteration of ash beds derived from igneous activity of Black Mountain, although no such beds were located.

Amorphous material in the area may be derived from physical and chemical weathering of quartz and possibly calcite. The amorphous material may be in a colloidal state or may be crystalline material that is small enough to appear amorphous in X-ray diffraction analysis.

Discussion

Davison (1969) reported that sand-sized calcite in Bear Lake is detrital in origin and that the clay-sized calcite and dolomite are possibly either detrital or precipitated directly from the water in Bear Lake. He stated that the calcite-dolomite ratios are random and indicated no apparent relationship between the occurrences of calcite and dolomite in Bear Lake. He further stated that no dolomite occurs in Bear Lake in front of North or South Eden Deltas but that calcite is found throughout the lake. He also concluded that the origin of the clay minerals is uncertain. Because Davidson lacked control of the effects of the drainage into Bear Lake, the present study was conducted to clarify the origin of the carbonates and clay minerals within Bear Lake.

The data in this report clarify the origin of sediments found by Davidson in Bear Lake. Clay-sized calcite and silt-sized calcite and dolomite are being transported by North Eden Creek into Bear Lake and therefore are detrital. Although no dolostones were identified in the study area, dolomite in minor amounts is being contributed to Bear Lake by North Eden Creek. The presence of dolomite perhaps is due to local occurrences in the Wasatch or Twin Creek Formations. Because calcite and minimal amounts of dolomite are supplied to Bear Lake by North Eden Creek, it is inferred that these minerals also are being carried into Bear Lake by other streams.

The fact that clay minerals in abundance are transported by North Eden Creek to at least station 4 and are present on North Eden Delta in minor amounts indicates that at least part of the clay minerals in Bear Lake are detrital in origin.

A decrease in grain size downstream is commonly reported in the literature. However, the opposite occurs in North Eden Creek, where maximum and mean grain sizes increase downstream. Downstream changes in mean particle size are related to four factors: (1) In the upper part of the stream, fine-grained particles of the Wasatch Formation and of disaggregated limestones of the Twin Creek Formation are contributed to the stream, whereas in the lower part large joint blocks of sandstones of the Nugget Formation are added to the stream. (2) Mass-wasting on steep canyon walls and additions of sediments from tributaries in the lower portion of the stream contribute larger particles than the same processes in the upper portion because the distance of transport is much shorter and the gradients of tributaries much steeper in the lower part. (3) Mechanical weathering occurs in the stream; however, the shortness of the stream does not allow the larger particles added in the lower part to be weathered into smaller particles rapidly enough to effectively reduce grain size downstream. (4) Chemical weathering reduces the particle size of the carbonates and silicates in the upper parts of the area before the particles are carried by low-gradient tributaries into North Eden Creek.

In the gravel size range the amount of calcite in North Eden Creek exhibits large fluctuations that are directly related to the total amount of gravel in each sample. The calcite that comes out of the Wasatch and Twin Creek Formations at the head of the stream is broken down quickly. As the stream flows past the Twin Creek Formation on the east side of the Sheep Creek Anticline, the amount of calcite in the gravel range increases. As the calcite is transported through the Nugget Formation its importance is decreased because little calcite is added to the stream. As North Eden Creek enters the west limb of the Sheep Creek Anticline and flows through the Twin Creek Formation, calcite again increases in importance. The amount of sand-sized calcite remains nearly constant because of additions of sand-sized calcite along the stream course, and mechanical weathering of gravel-sized calcite where the stream passes through the Nugget Formation.

In the silt-size range, the amount of calcite varies in the upper portion of North Eden Creek but becomes more constant in the lower part of the stream. As a result of mechanical weathering in the headwaters of the stream, the amount of silt-sized calcite increases downstream; whereas the amount of gravel-sized calcite decreases.

The Twin Creek Formation lies near the surface in much of the upper part of North Eden Creek and is an apparent source of calcite. However, the samples taken farthest upstream (stations 12-13), where the Wasatch is thick enough to prevent the Twin Creek Formation from contributing to the stream, still contain calcite, which indicates that the Wasatch Formation is also a source of calcite for North Eden Creek. In the lower portion of North Eden Creek, the relative amount of calcite is nearly constant, so that tributaries must contribute nearly proportional amounts of calcite to the stream. The calcite comes from the cap of Wasatch Formation on the Bear Lake Plateau and from outcrops of Twin Creek Formation on the east and west sides of Sheep Creek Anticline. Member C of the Twin Creek Formation is exceedingly fine-grained and probably supplies considerable amounts of clay-sized calcite to tributaries of North Eden Creek.

Quartz is the dominant mineral in the silt, sand, and gravel size ranges, except in the silt ranges of samples 1 and 3B where it is between 15 and 50 percent, and in the gravel of sample 14 where there were only two particles and both were calcite. Quartz, present in all the formations in the area, comes from the Wasatch Formation in the upper part of North Eden Creek, with the possibility of a minor source of quartz from Member G of the Twin Creek Formation. Large amounts of silt- and clay-sized quartz in the upper portion of a stream perhaps is unusual. However, in North Eden Creek, the abundance of quartz in the silt- and clay-size range may be due to the small particle size of the source rock (Wasatch Formation and Member G of the Twin Creek Formation). Quartz is added to the lower portion of the stream by tributaries and by mass-wasting fromthe Nugget Formation comprising the steep canyon walls of North Eden Canyon.

Dolomite occurs less frequently in the study area than the other minerals. However, it is an important constituent. It is present in samples 1, 4, and 11 in the silt-size range and in samples 4 and 14 in the very fine sand-size range. No dolomitic formations are present within the drainage area of North Eden Creek; the presence of dolomite, therefore, is probably due to local occurrences in the

Wasatch Formation.

Although Black Mountain is a dominant feature on the southern drainage boundary, and headwaters of tributaries reach to within two miles of Black Mountain, any contributions to the mineralogy of North Eden Creek are difficult to recognize. Mineralogy of the sediments is neither diagnostic nor characteristic of a basalt source. Some or most feldspar found in stream sediment samples must come from a source other than Black Mountain; this is shown by the presence of feldspars in upper portions of North Eden Creek, which do not have tributaries draining Black Mountain. Minor montmorillonite may reflect igneous activity associated with Black Mountain.

CONCLUSIONS

Prior to man's activities, North Eden Creek transported considerable amounts of sediment into Bear Lake. Some of this sediment remains at the stream mouth as North Eden Delta. During transportation minerals are broken down chemically and by abrasion into smaller particles and/or new minerals. However, the distance of transport within the drainage of North Eden Creek is so short that abrasion and chemical alteration are reduced in importance; local changes in lithology along the stream predominate in determining the grain sizes and minerals carried by each segment of the stream.

The stream transports quartz and calcite in gravel, sand, silt, and clay sizes. This provides one definite source for silt- and clay-sized calcite in Bear Lake. The stream also transports a significant amount of amorphous material in the $< .00049$ mm range, again a common constituent of sediments in Bear Lake. Very minor amounts of dolomite also are present within the stream samples studied.

Davidson (1969, p. 43) suggested that clay-sized calcite may be precipitating in Bear Lake at the present time or perhaps did during the Pleistocene Epoch. Calcite in the form of overgrowths on quartz grains and aggregated clay-sized particles has been and is now being deposited in Bear Lake by North Eden Creek. It also is brought to the lake as detrital particles of sand, silt, and coarse clay. Much of the amorphous material in Bear Lake probably also is detrital.

Although others have made geologic studies in this area, no other detailed report of the drainage of North Eden Creek has been written. This account clarifies Davidson's hypotheses on the origin of the carbonate minerals in the sediments of Bear Lake and presents information on the origin of clay minerals and amorphous materials in Bear Lake. The present study concludes that Black Mountain is the eroded remnant of a volcanic vent rather than the remnants of lava flows as previously reported. The study also provides a more detailed geologic map of the area than was available previously.

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APPENDIXES

Appendix A

Size-Frequency Distributions and Cumulative-Weight Percentages

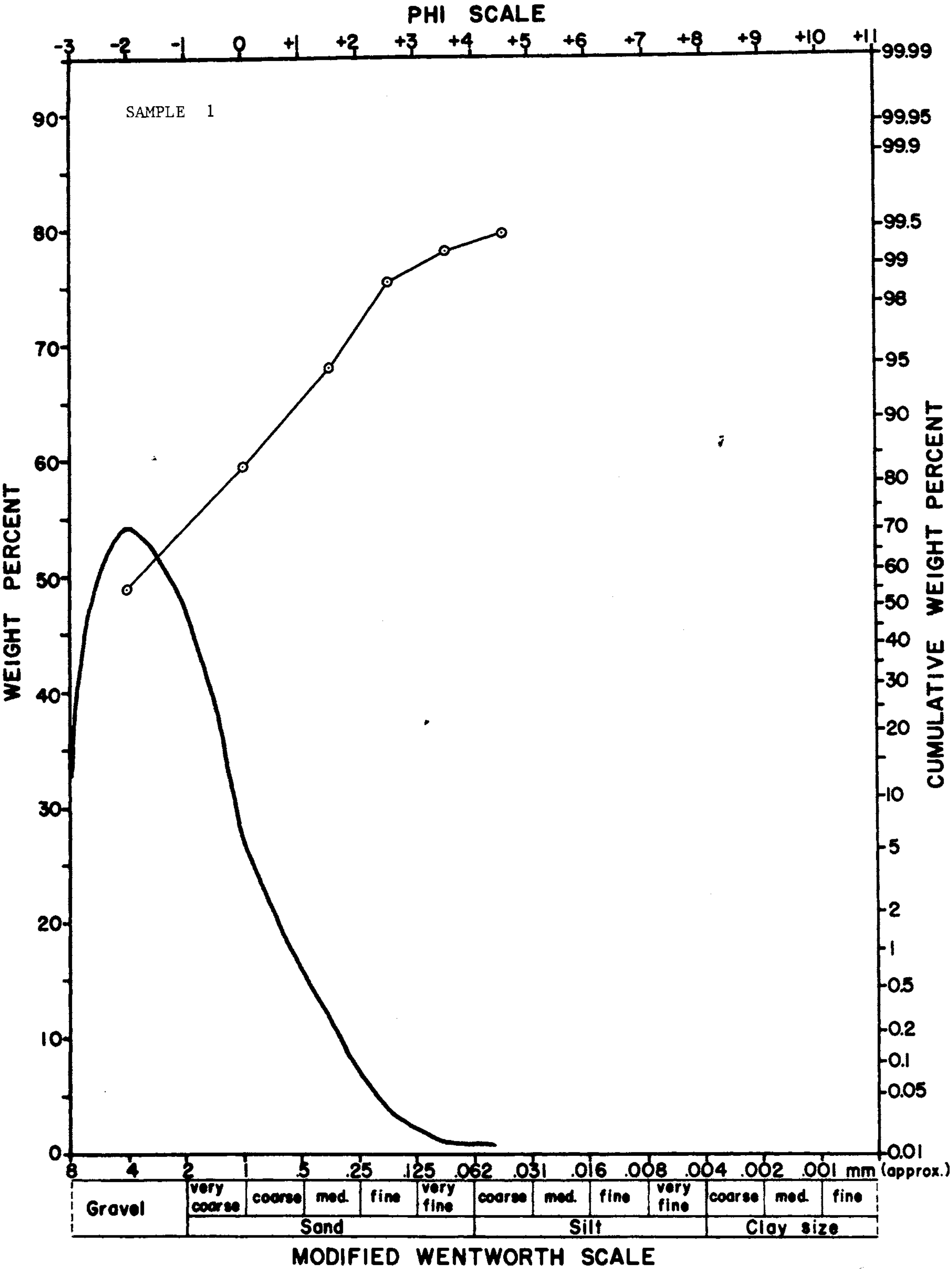
Sample Number

Size in mm.	1	2	3A	3B	4
>2.	54.4	56.5	37.2	46.9	17.2
.5	27.5	15.8	17.6	26.3	8.0
.25	12.5	8.8	21.0	17.4	8.5
.125	4.0	5.6	5.6	4.1	13.3
.062	0.7	4.8	3.6	1.9	14.8
.037	0.3	3.3	2.3	.5	13.4
.004	0.5	5.1	12.5	2.8	19.6
< .00049	----	----	----	----	5.1

	5	6	7	8	9
>2.	12.1	40.0	0.3	0.02	17.8
.5	8.4	10.2	0.9	1.4	8.6
.25	8.1	8.2	5.8	8.4	5.5
.125	21.3	12.9	11.6	16.4	9.9
.062	16.3	7.7	12.8	12.9	10.5
.037	18.8	6.4	39.4	29.7	19.7
.004	13.7	14.4	6.6	29.5	23.1
< .00049	1.1	----	22.5	1.6	4.8

	10	11	12	13	14
>2.	5.4	0.8	57.4	2.2	0.3
.5	9.4	14.2	11.9	6.9	6.2
.25	14.1	13.7	6.5	10.4	11.3
.125	16.9	18.1	6.3	12.7	17.7
.062	12.5	13.2	4.4	12.9	16.2
.037	20.3	21.9	4.1	34.5	26.7
.004	19.3	16.8	9.3	19.0	20.4
< .00049	2.0	1.2	----	1.3	1.1

	Delta average	Main stream average	Tributary average	Over-all average
>2.	48.8	11.1	18.9	26.5
.5	21.8	8.3	7.0	12.4
.25	14.9	9.7	7.9	10.8
.125	4.8	15.3	12.5	10.9
.062	2.8	12.9	11.0	8.9
.037	1.6	22.1	20.1	14.6
.004	5.2	15.7	20.6	13.8
< .00049	----	4.8	1.9	2.2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SAMPLE 1
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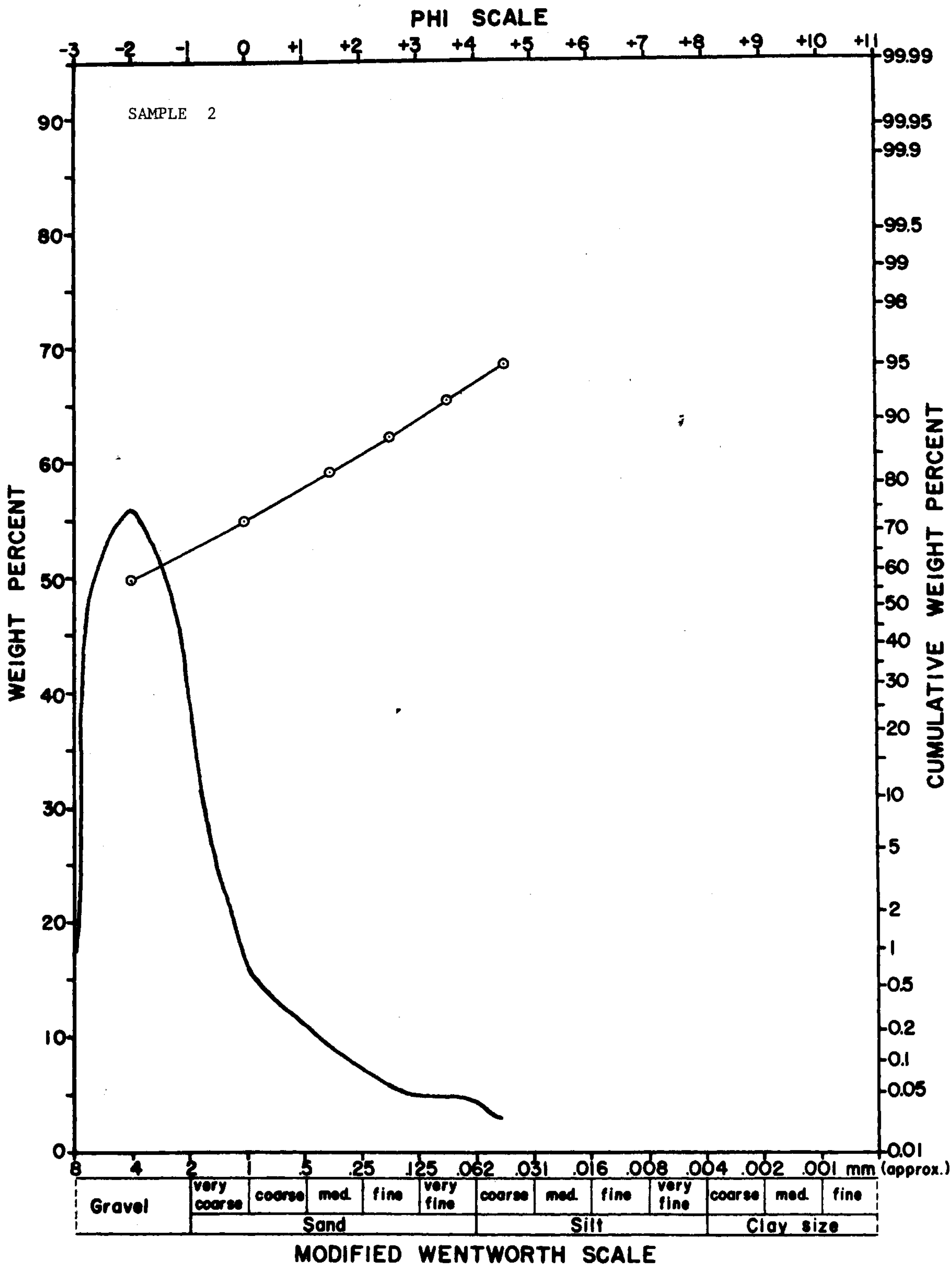
CUMULATIVE WEIGHT PERCENT
0.01 0.05 0.1 0.2 0.5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.5 99.9 99.95 99.99
8 4 2 1 .5 .25 .125 .062 .031 .016 .008 .004 .002 .001 mm (approx.)
Gravel
very coarse
coarse
med.
fine
very fine
Sand
coarse
med.
fine
very fine
Silt
coarse
med.
fine
Clay size
MODIFIED WENTWORTH SCALE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SAMPLE 2
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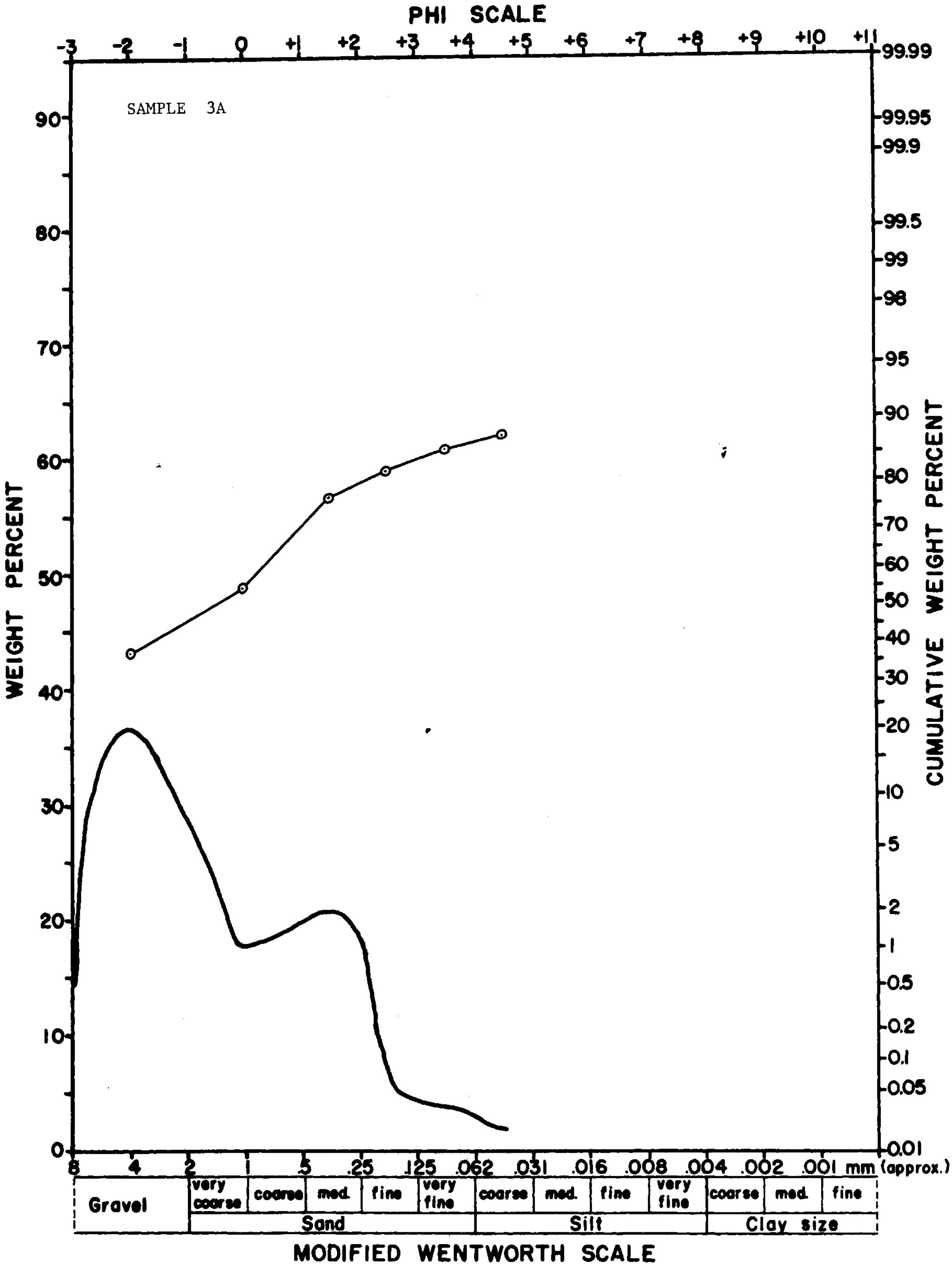
CUMULATIVE WEIGHT PERCENT
0.01 0.05 0.1 0.2 0.5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.5 99.9 99.95 99.99
8 4 2 1 .5 .25 .125 .062 .031 .016 .008 .004 .002 .001 mm (approx.)
Gravel
very coarse
coarse
med.
fine
very fine
coarse
med.
fine
very fine
coarse
med.
fine
Sand
Silt
Clay size
MODIFIED WENTWORTH SCALE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SAMPLE 3A
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CUMULATIVE WEIGHT PERCENT
0.01 0.05 0.1 0.2 0.5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.5 99.9 99.95 99.99
8 4 2 1 .5 .25 .125 .062 .031 .016 .008 .004 .002 .001 mm (approx.)
Gravel
very coarse
coarse
med.
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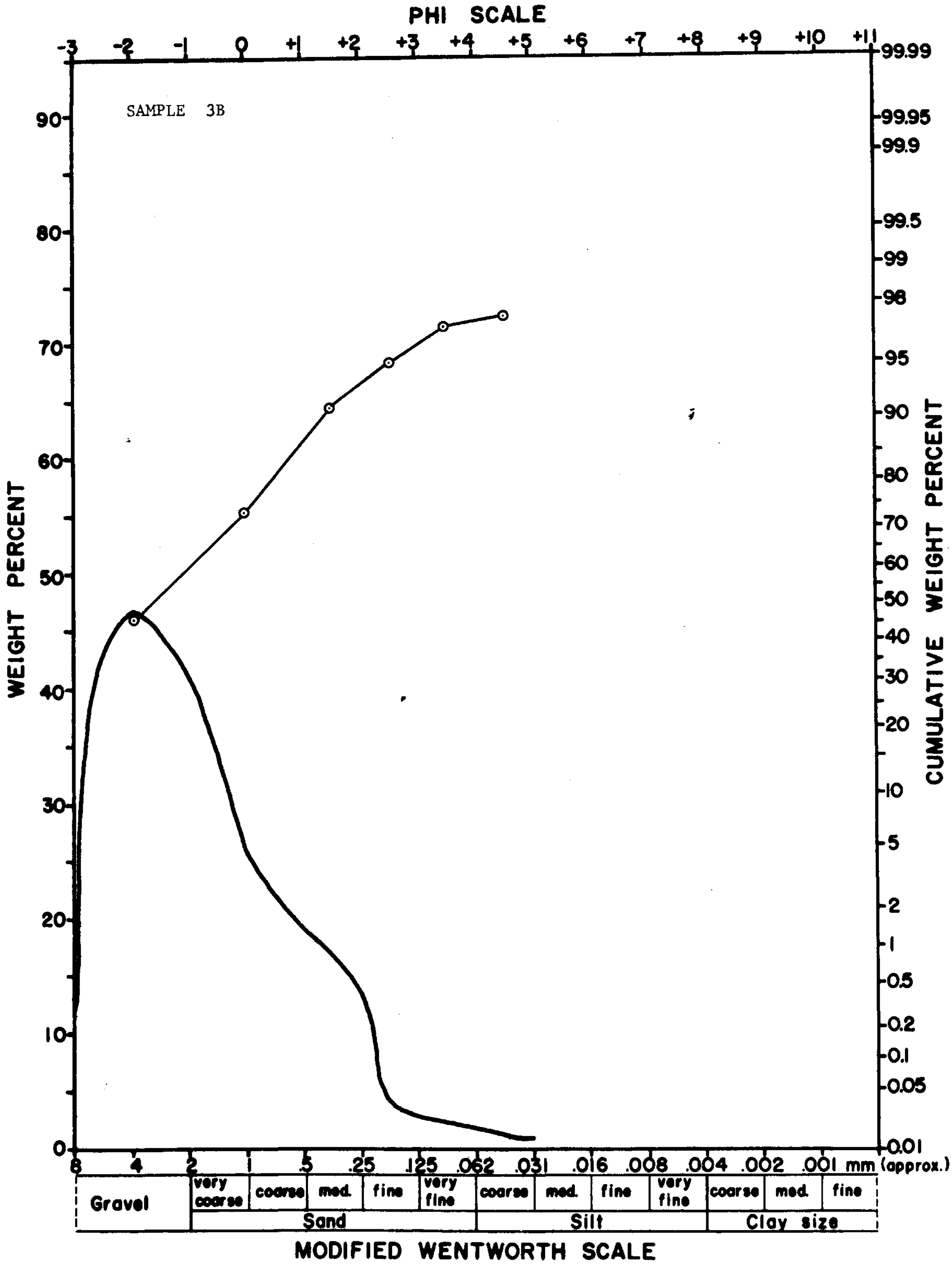
med.
fine
very fine
coarse
med.
fine
Sand
Silt
Clay size
MODIFIED WENTWORTH SCALE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SAMPLE 3B
WEIGHT PERCENT
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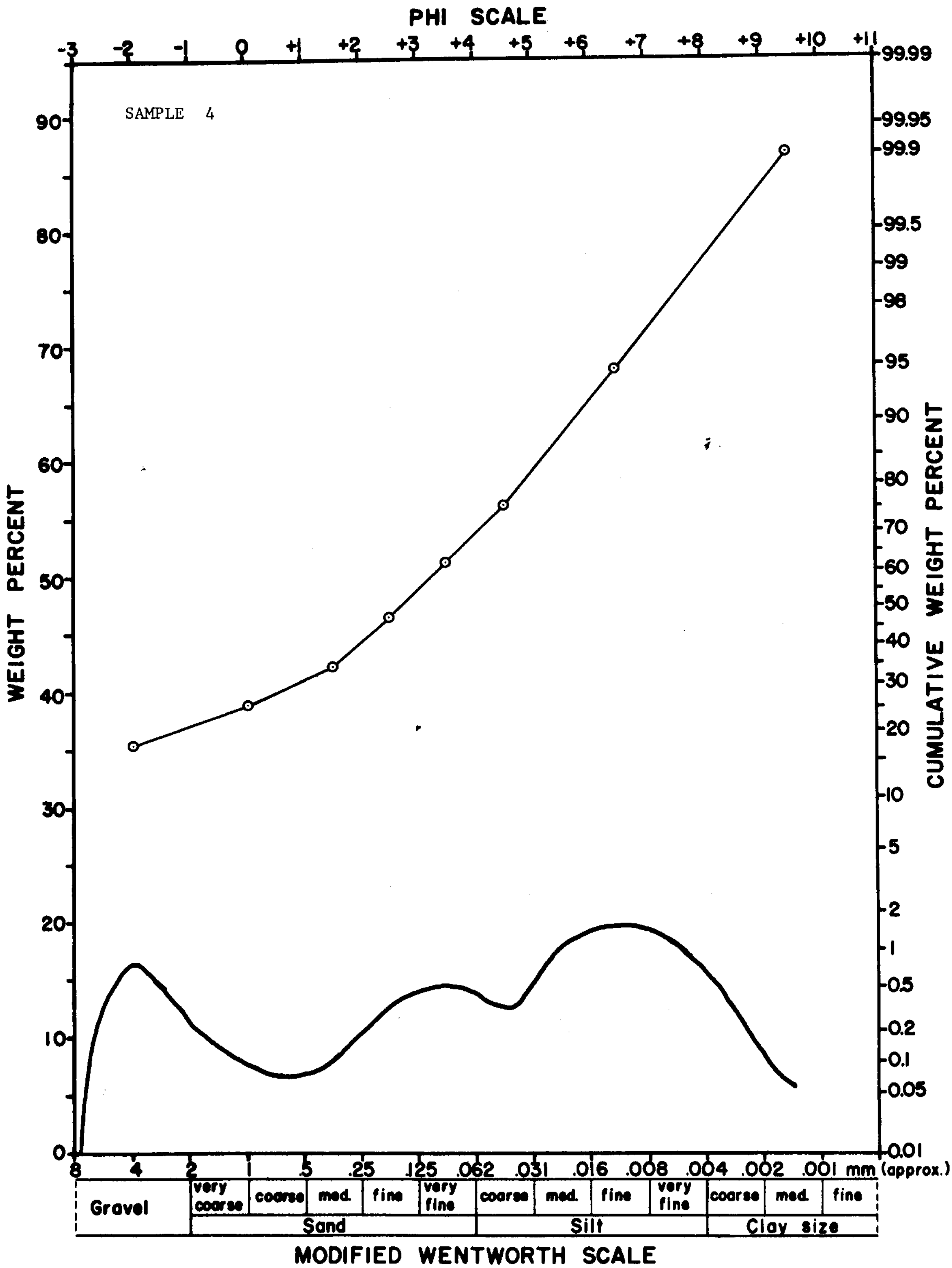
CUMULATIVE WEIGHT PERCENT
99.99 99.95 99.9 99.5 99 98 95 90 80 70 60 50 40 30 20 10 5 2 1 0.5 0.2 0.1 0.05 0.01
8 4 2 1 .5 .25 .125 .062 .031 .016 .008 .004 .002 .001 mm (approx.)
Gravel
very coarse
coarse
med.
fine
very fine
coarse
med.
fine
very fine
coarse
med.
fine
Sand
Silt
Clay size
MODIFIED WENTWORTH SCALE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SAMPLE 4
WEIGHT PERCENT
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CUMULATIVE WEIGHT PERCENT
0.01 0.05 0.1 0.2 0.5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.5 99.9 99.95 99.99
8 4 2 1 .5 .25 .125 .062 .031 .016 .008 .004 .002 .001 mm (approx.)
Gravel
very coarse
coarse
med.
fine
very fine
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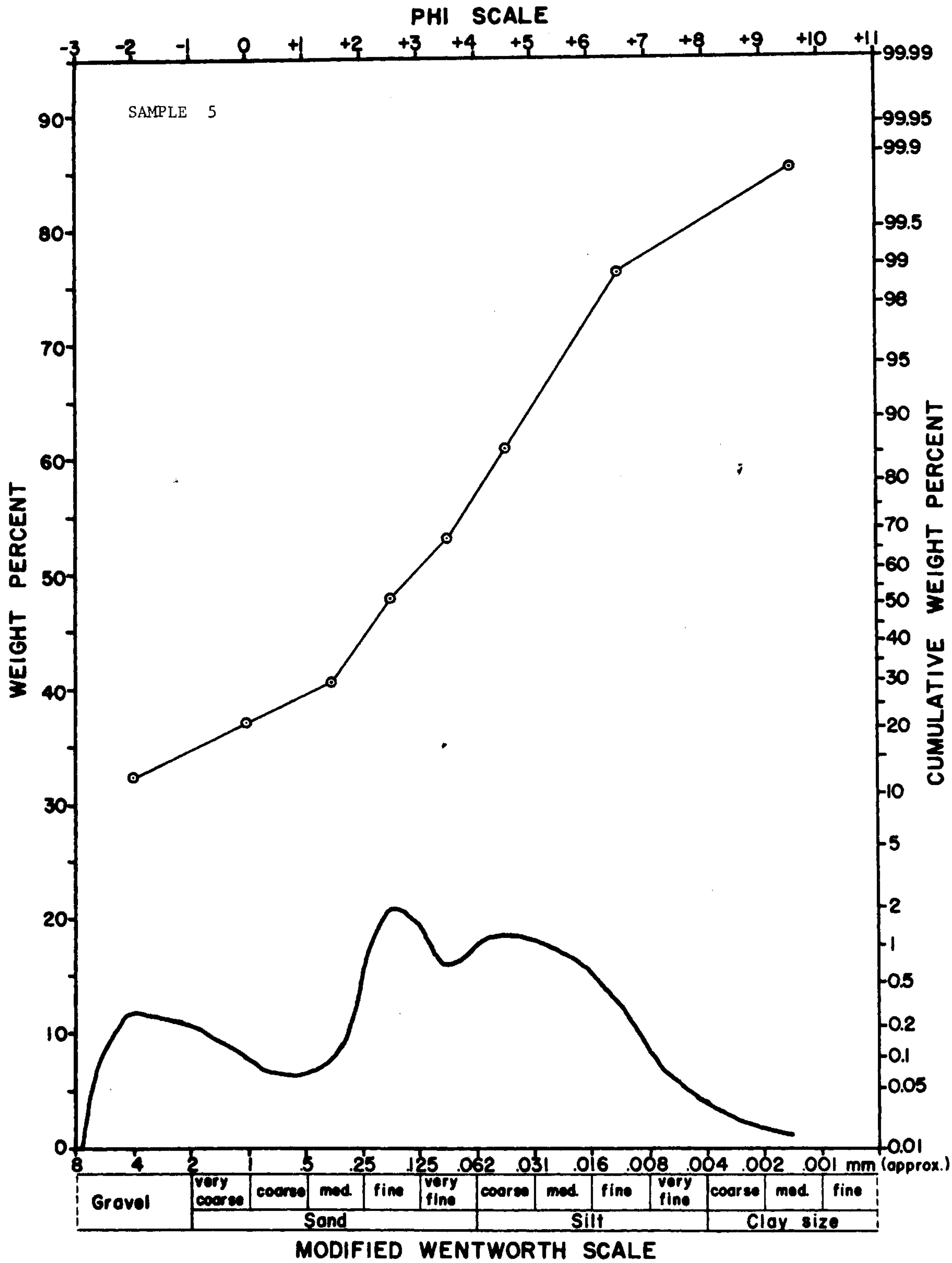
Sand
Silt
Clay size
MODIFIED WENTWORTH SCALE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CUMULATIVE WEIGHT PERCENT
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0.01 0.05 0.1 0.2 0.5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.5 99.9 99.95 99.99
8 4 2 1 .5 .25 .125 .062 .031 .016 .008 .004 .002 .001 mm (approx.)
Gravel
very coarse
coarse
med.
fine
very fine
Sand
coarse
med.
fine
very fine
Silt
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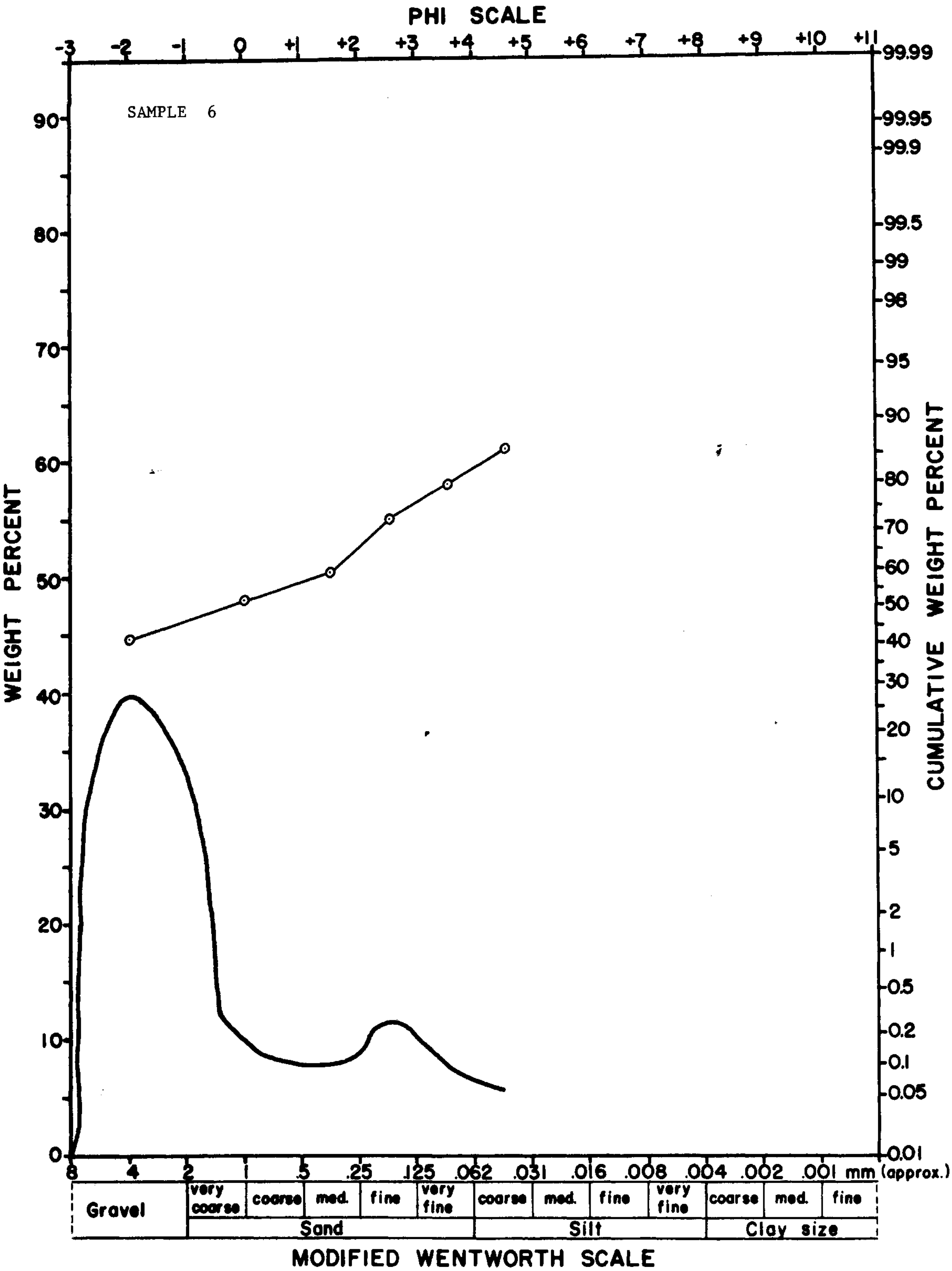
Clay size
MODIFIED WENTWORTH SCALE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WEIGHT PERCENT
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CUMULATIVE WEIGHT PERCENT
99.99 99.95 99.9 99.5 99 98 95 90 80 70 60 50 40 30 20 10 5 2 1 0.5 0.2 0.1 0.05 0.01
8 4 2 1 .5 .25 .125 .062 .031 .016 .008 .004 .002 .001 mm (approx.)
Gravel
very coarse
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med.
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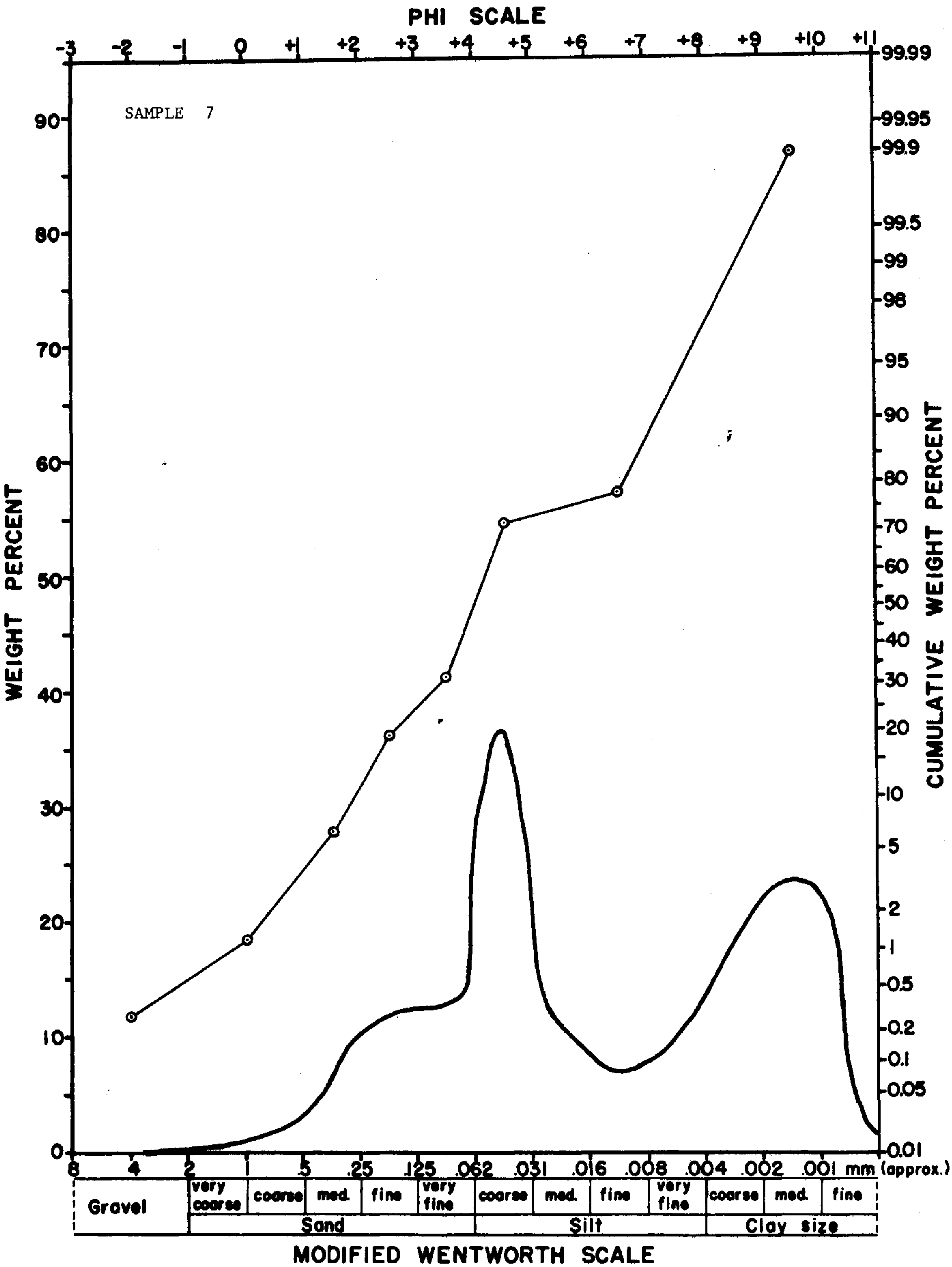
Sand
Silt
Clay size
MODIFIED WENTWORTH SCALE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SAMPLE 7
WEIGHT PERCENT
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CUMULATIVE WEIGHT PERCENT
0.01 0.05 0.1 0.2 0.5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.5 99.9 99.95 99.99
8 4 2 1 .5 .25 .125 .062 .031 .016 .008 .004 .002 .001 mm (approx.)
Gravel
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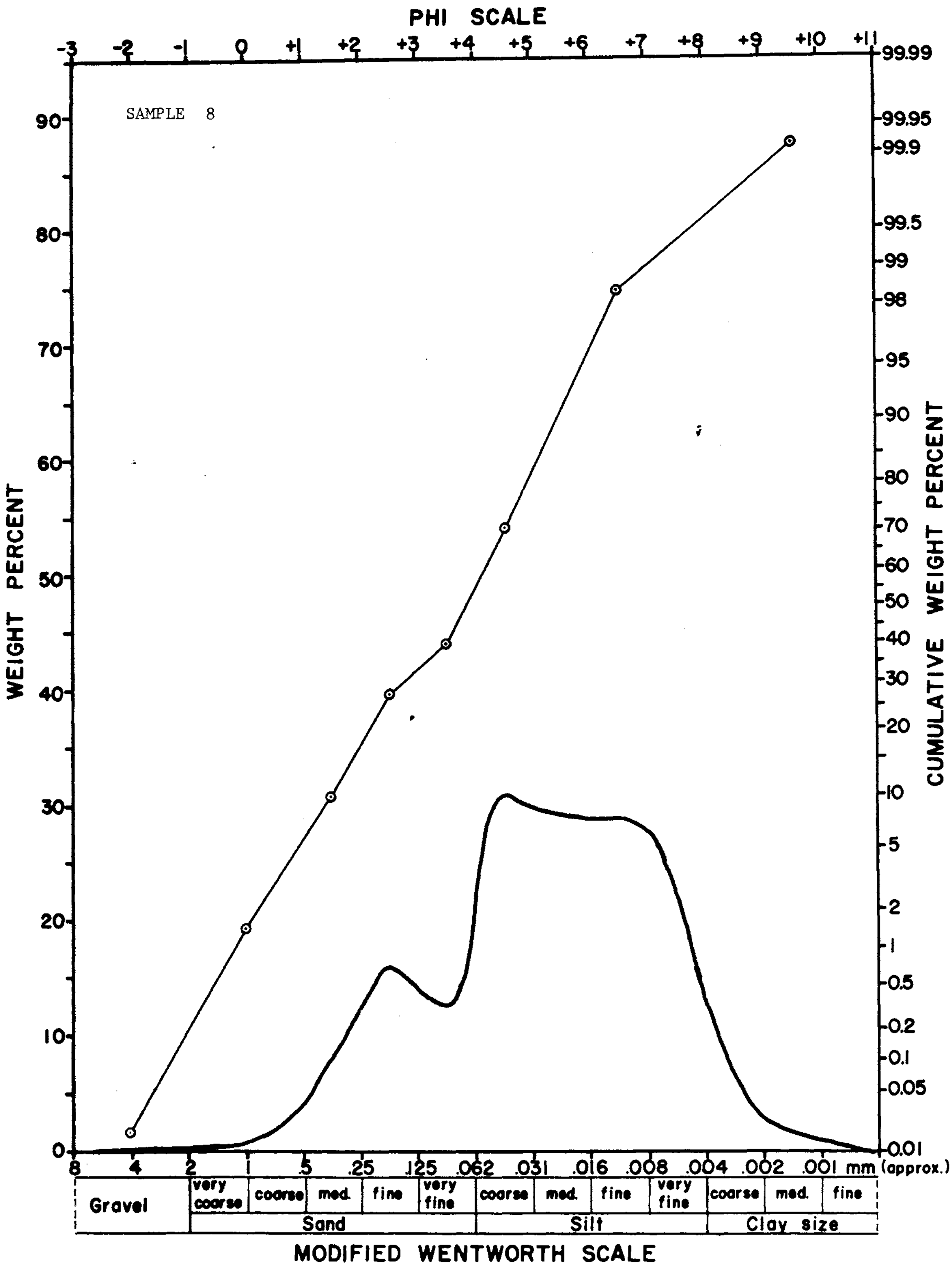
MODIFIED WENTWORTH SCALE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SAMPLE 8
WEIGHT PERCENT
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CUMULATIVE WEIGHT PERCENT
0.01 0.05 0.1 0.2 0.5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.5 99.9 99.95 99.99
8 4 2 1 .5 .25 .125 .062 .031 .016 .008 .004 .002 .001 mm (approx.)
Gravel
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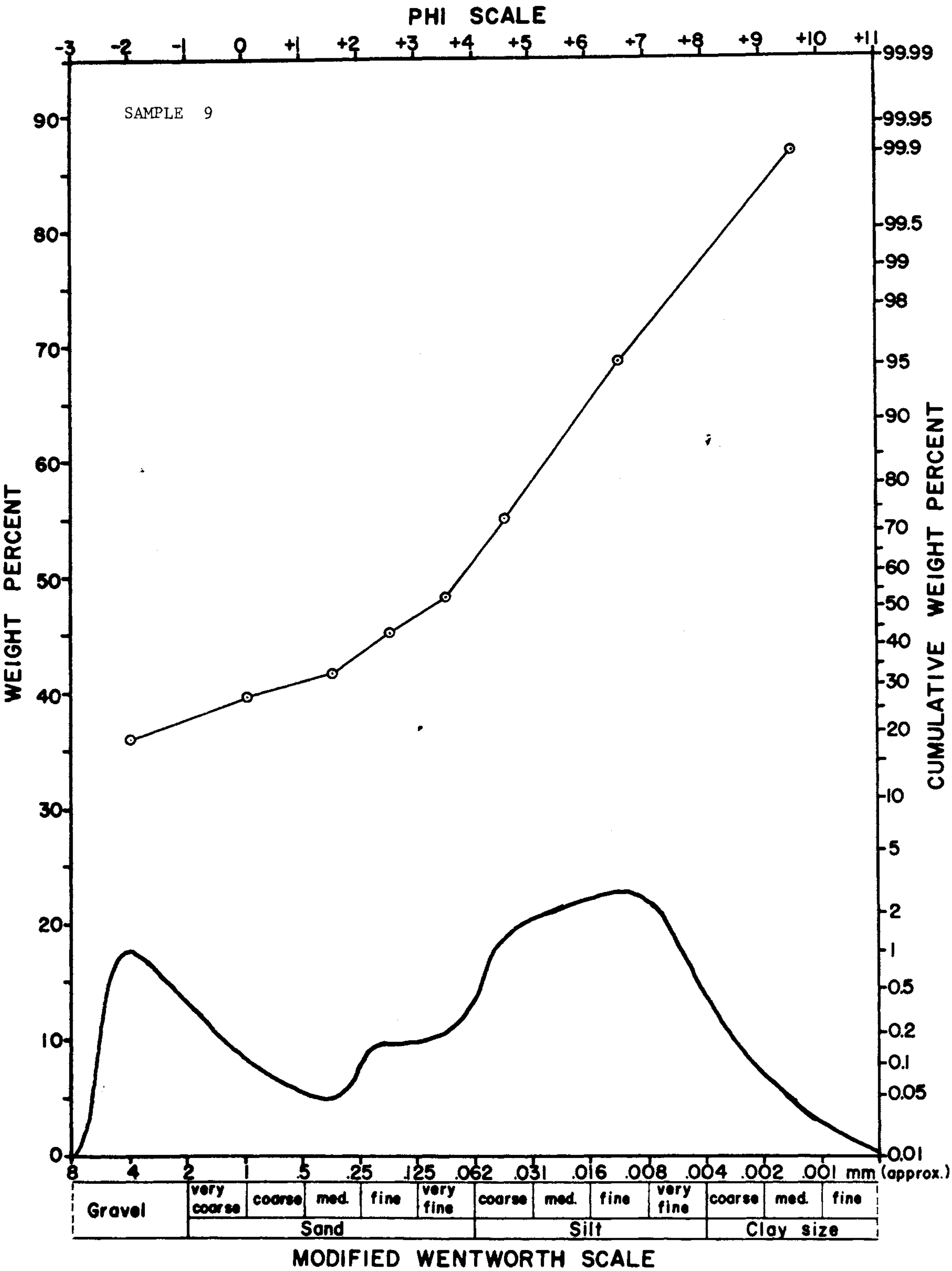
MODIFIED WENTWORTH SCALE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SAMPLE 9
WEIGHT PERCENT
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CUMULATIVE WEIGHT PERCENT
0.01 0.05 0.1 0.2 0.5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.5 99.9 99.95 99.99
8 4 2 1 .5 .25 .125 .062 .031 .016 .008 .004 .002 .001 mm (approx.)
Gravel
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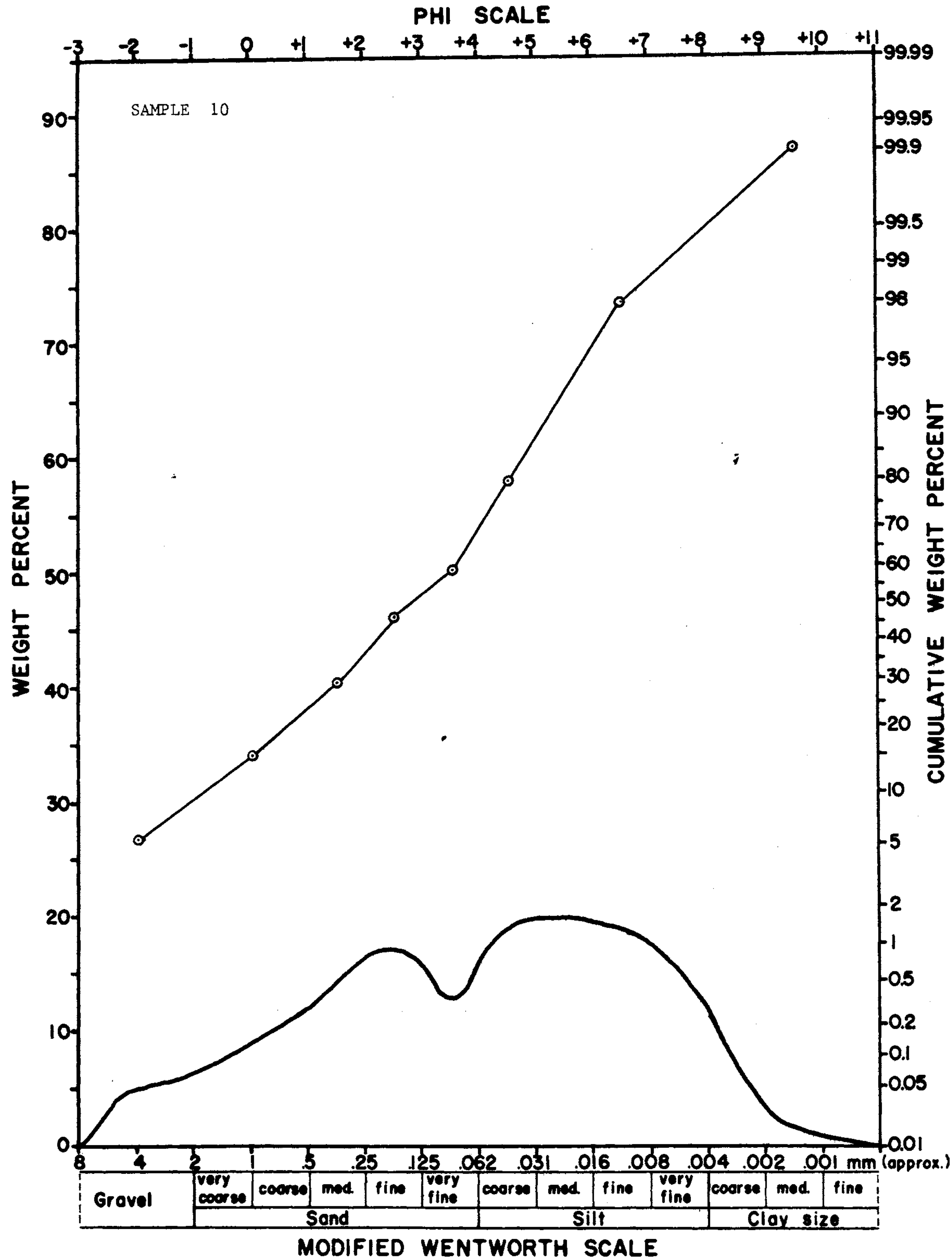
MODIFIED WENTWORTH SCALE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WEIGHT PERCENT
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CUMULATIVE WEIGHT PERCENT
0.01 0.05 0.1 0.2 0.5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.5 99.9 99.95 99.99
8 4 2 1 .5 .25 .125 .062 .031 .016 .008 .004 .002 .001 mm (approx.)
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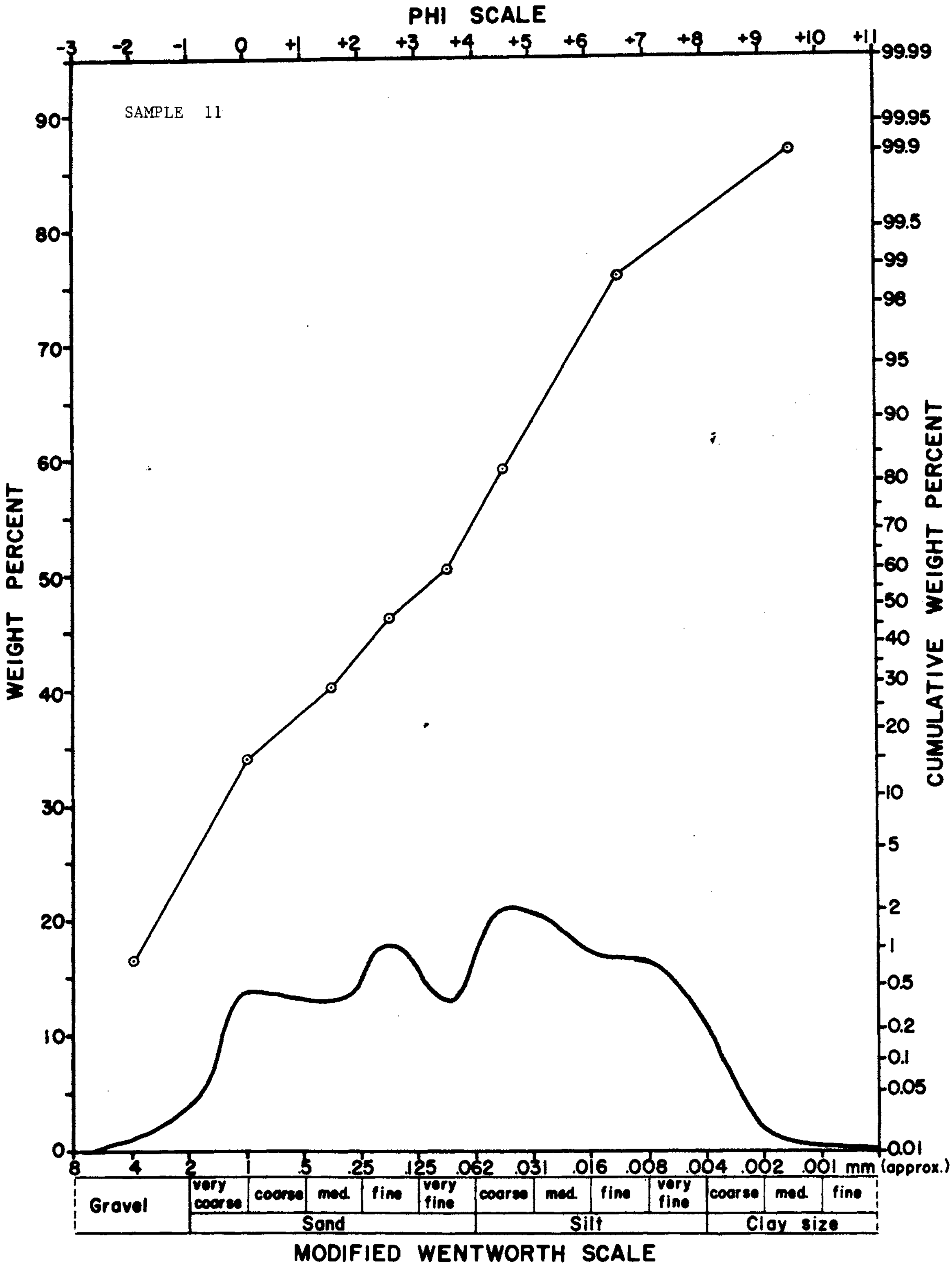
MODIFIED WENTWORTH SCALE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SAMPLE 11
WEIGHT PERCENT
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CUMULATIVE WEIGHT PERCENT
99.99 99.95 99.9 99.5 99 98 95 90 80 70 60 50 40 30 20 10 5 2 1 0.5 0.2 0.1 0.05 0.01
8 4 2 1 .5 .25 .125 .062 .031 .016 .008 .004 .002 .001 mm (approx.)
Gravel
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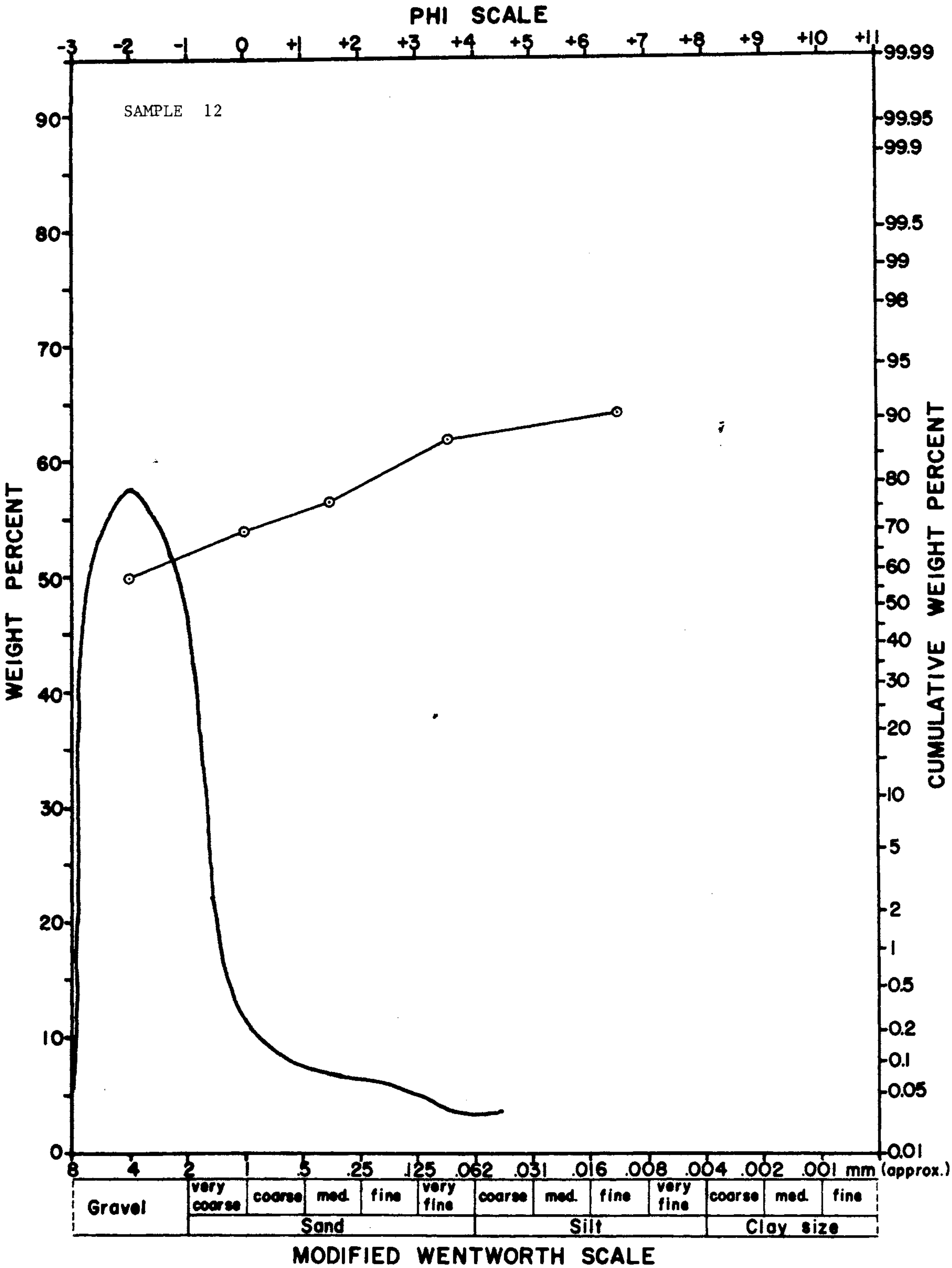
MODIFIED WENTWORTH SCALE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WEIGHT PERCENT
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CUMULATIVE WEIGHT PERCENT
0.01 0.05 0.1 0.2 0.5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.5 99.9 99.95 99.99
8 4 2 1 .5 .25 .125 .062 .031 .016 .008 .004 .002 .001 mm (approx.)
Gravel
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Silt
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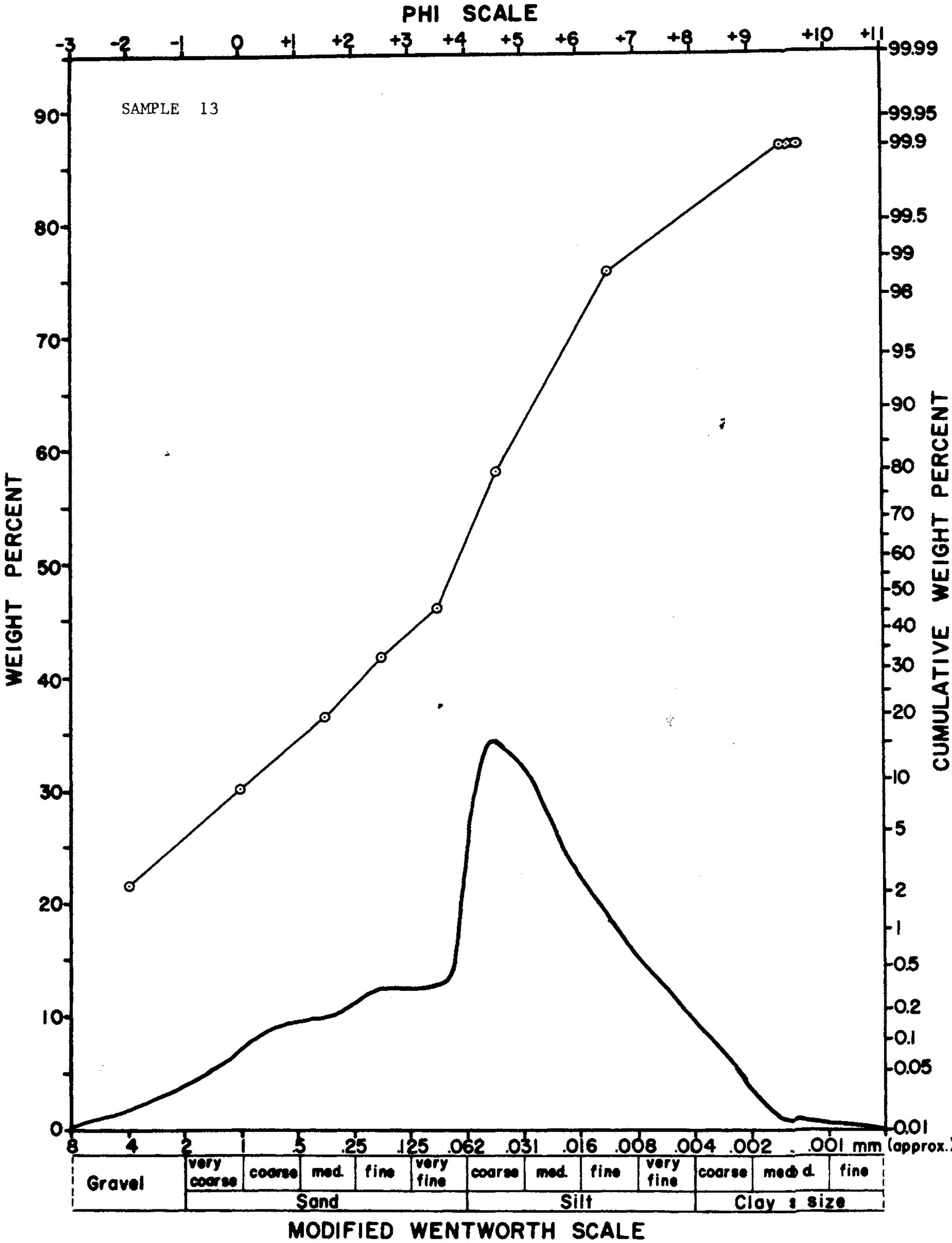
Clay size
MODIFIED WENTWORTH SCALE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-1
0
+1
+2
+3
+4
+5
+6
+7
+8
+9
+10
+11
SAMPLE 13
WEIGHT PERCENT
CUMULATIVE WEIGHT PERCENT
99.99
99.95
99.9
99.5
99
98
95
90
80
70
60
50
40
30
20
10
5
2
1
0.5
0.2
0.1
0.05
0.01
8
4
2
1
.5
.25
.125
.062
.031
.016
.008
.004
.002
.001 mm (approx.)
Gravel
very coarse
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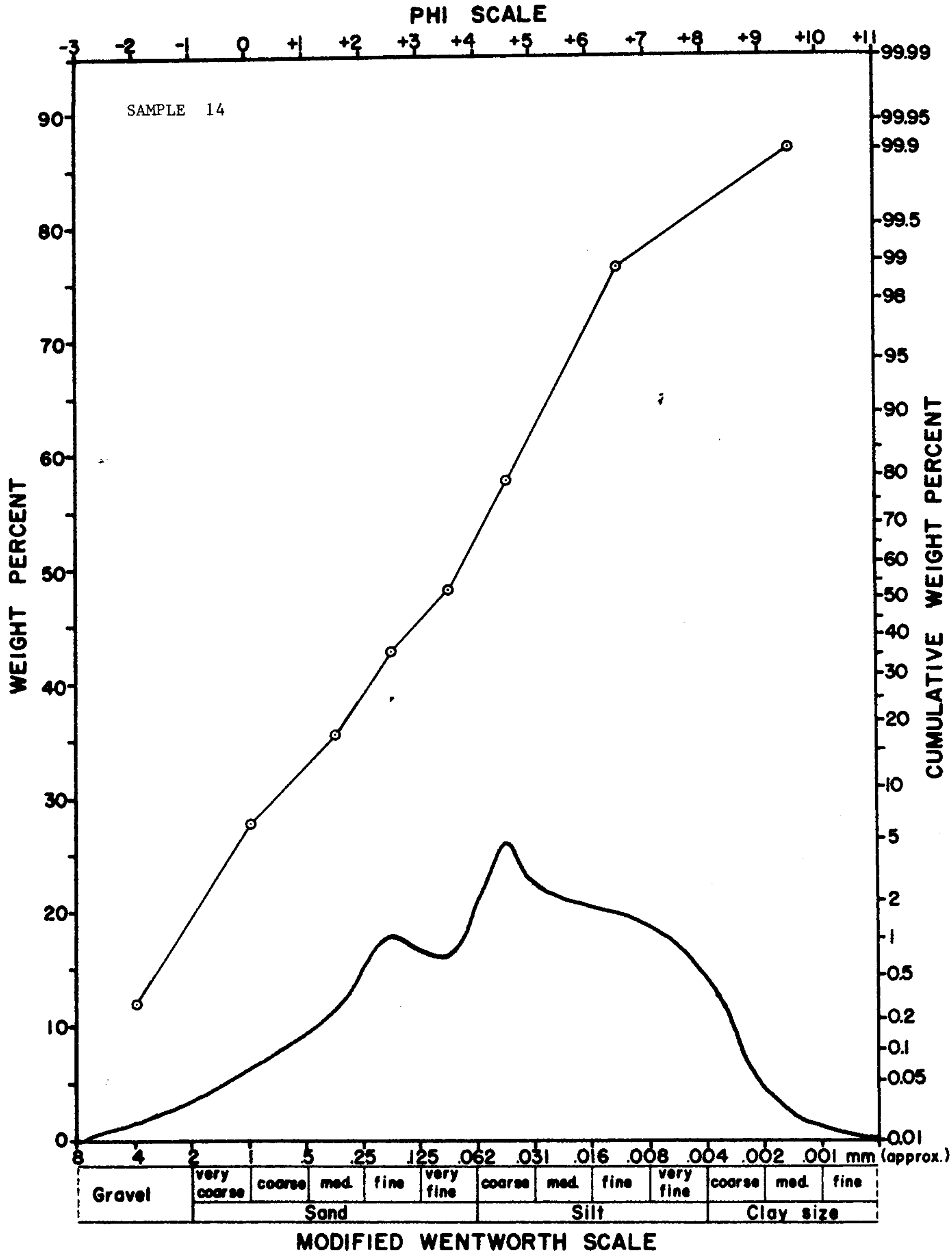
Sand
Silt
Clay size
MODIFIED WENTWORTH SCALE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-3 -2 -1 0 +1 +2 +3 +4 +5 +6 +7 +8 +9 +10 +11
SAMPLE 14
WEIGHT PERCENT
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CUMULATIVE WEIGHT PERCENT
99.99 99.95 99.9 99.5 99 98 95 90 80 70 60 50 40 30 20 10 5 2 1 0.5 0.2 0.1 0.05 0.01
8 4 2 1 .5 .25 .125 .062 .031 .016 .008 .004 .002 .001 mm (approx.)
Gravel
very coarse
coarse
med.
fine
very fine
coarse
med.
fine
very fine
coarse
med.
fine
Sand
Silt
Clay size
MODIFIED WENTWORTH SCALE

Appendix B

Mineral Abundances in Each Size Fraction

D = Dominant mineral (>50 percent) I = Important mineral (15-50 percent) M = Minor mineral (1-15 percent)

Sample Number	Size Fraction	Amorphous	Kaolinite	Illite	Montmorillonite	Calcite	Dolomite	Feldspar	Quartz
1	>2.					I			D
	.5-2					I			D
	.125-.5					I			D
	< .037			M		D	I		I
2	>2.					M			D
	.5-2					M			D
	.125-.5					I			D
	< .037					I		M	D
3A	>2.					M			D
	.5-2					M			D
	.125-.5					M			D
	< .037					I		M	D
3B	>2.					M			D
	.5-2					M			D
	.125-.5					M			D
	< .037					D			I

Sample Number	Size Fraction	Amorphous	Kaolinite	Illite	Montmoril-lonite	Calcite	Dolomite	Feldspar	Quartz
4	>2.					M			D
	.5-2					M			D
	.125-.5					I	M		D
	.0039-.031		M	M		I	I	M	D
	.00049-.0039	D	I	I					
	< .00049	D	M						
5	>2.								D
	.5-2					M			D
	.125-.5					M			D
	.0039-.031		I	I		I		I	D
	.00049-.0039		D	I					I
	< .00049	D	I						
6	>2.					I			D
	.5-2					I			D
	.125-.5					I			D
	< .037		M			I		M	D

Sample Number	Size Fraction	Amorphous	Kaolinite	Illite	Montmorillonite	Calcite	Dolomite	Feldspar	Quartz
7	>2.	Quartz and calcite mixed in each grain							
	.5-2					I			D
	.125-.5					I			D
	.0039-.031		M	M		M		M	D
	.00049-.0039	D	I						
	< .00049	D	M	M					
8	>2.	One grain of quartz							
	.5-2					I			D
	.125-.5					I		M	D
	.0039-.031		M	I				I	D
	.00049-.0039		D	I					
	< .00049	D							
9	>2.					I			D
	.5-2					I			D
	.125-.5					I			D
	.0039-.031		M	M		I			D
	.00049-.00039		D	I		I			
	< .00049		M						

Sample Number	Size Fraction	Amorphous	Kaolinite	Illite	Montmorillonite	Calcite	Dolomite	Feldspar	Quartz
10	>2.					I			D
	.5-2					I			D
	.125-.5					I			D
	.0039-.031		M	M	M			M	D
	.00049-.0039		D	I					
	< .00049	D	M						
11	>2.								D
	.5-2					I			D
	.125-.5					I			D
	.0039-.031			M		I	I	I	D
	.00049-.0039		I	I		I			
	< .00049	D							
12	>2.					M			D
	.5-2					M			D
	.125-.5					M			D
	< .037		M						D

Sample Number	Size Fraction	Amorphous	Kaolinite	Illite	Montmorillonite	Calcite	Dolomite	Feldspar	Quartz
13	>2.					I			D
	.5-2					M			D
	.125-.5					M			D
	.0039-.031		I	I				I	D
	.00049-.0039		K	I					
	< .00049	D	I						
14	>2.	Two grains, both calcite							
	.5-2					I			D
	.125-.5					I	M		D
	.0039-.031		I	I		I			D
	.00049-.0039		D	I		M			
	< .00049	D	I						

VITA

Larry William McClurg

Candidate for the Degree of

Master of Science

Thesis: Source Rocks and Sediments in Drainage Area of North Eden Creek, Bear Lake Plateau, Utah-Idaho

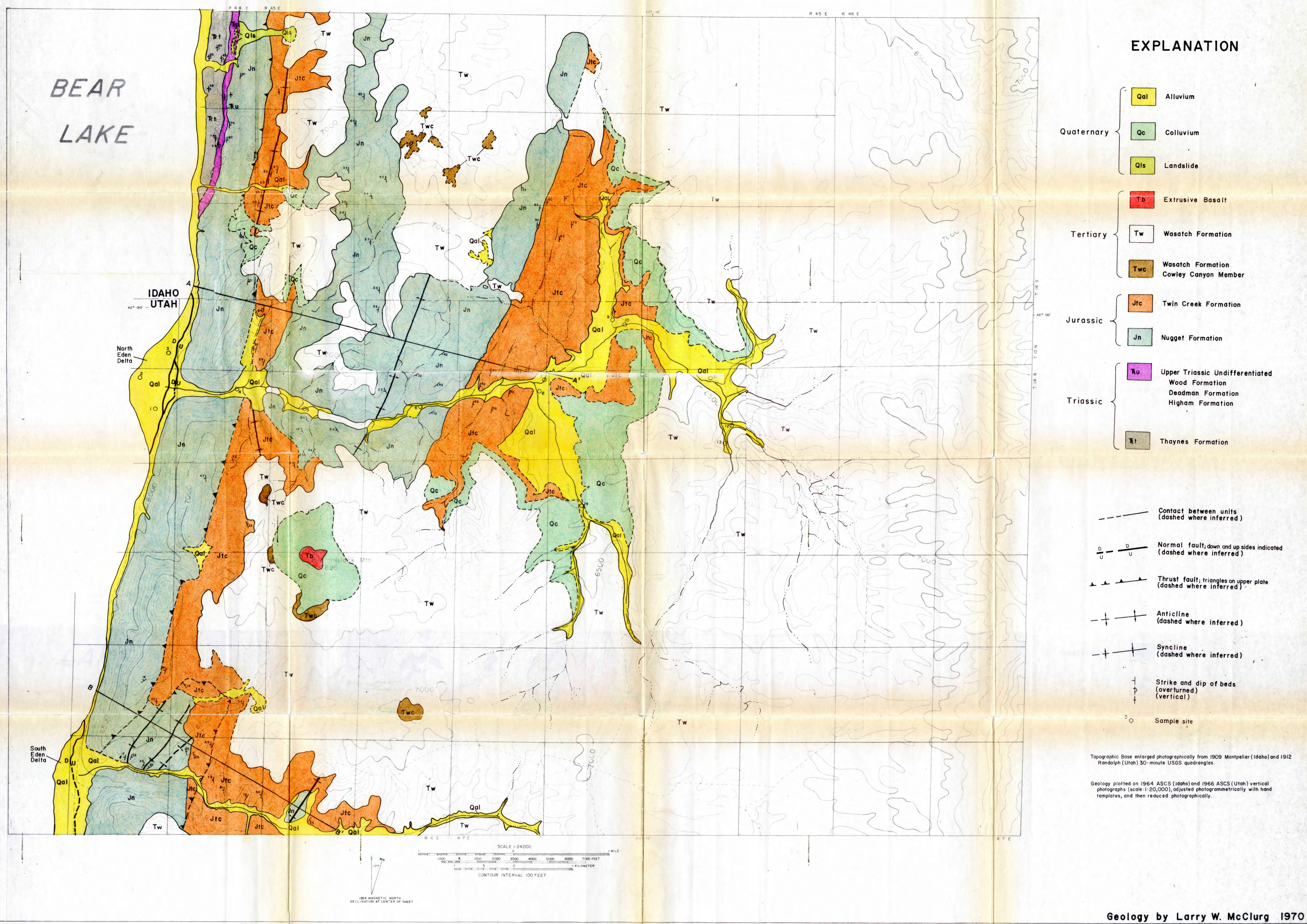
Major Field: Geology

Biographical Information:

Personal Data: Born in Salt Lake City, Utah, April 30, 1940, son of John Otto and Katie McClurg; married Kolette Montague December 29, 1966.

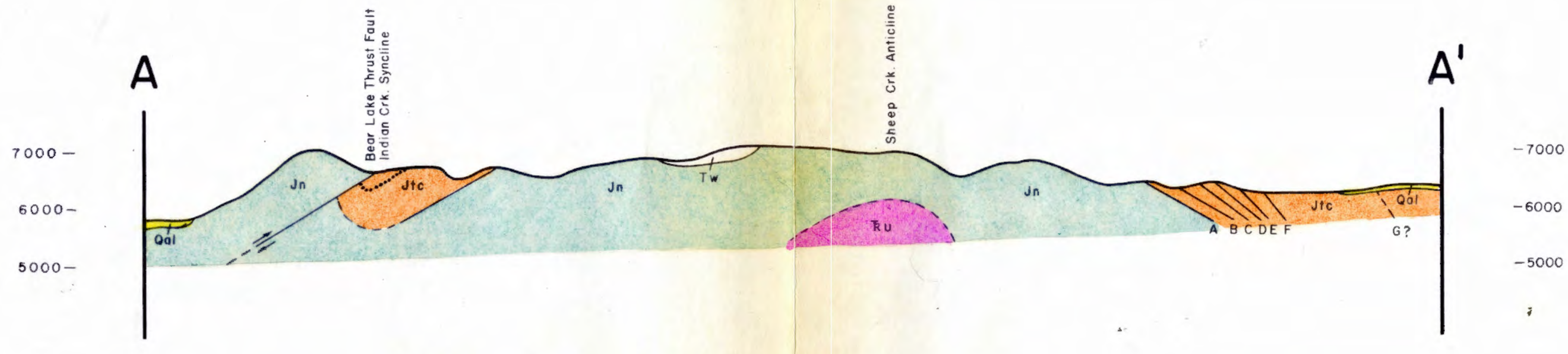
Education: Attended elementary school in Bountiful, Utah; graduated from Bountiful High School in 1958; received the Bachelor of Science Degree from Utah State University, with a major in geology, in 1968; completed requirements for the Master of Science Degree in geology at Utah State University in 1970.

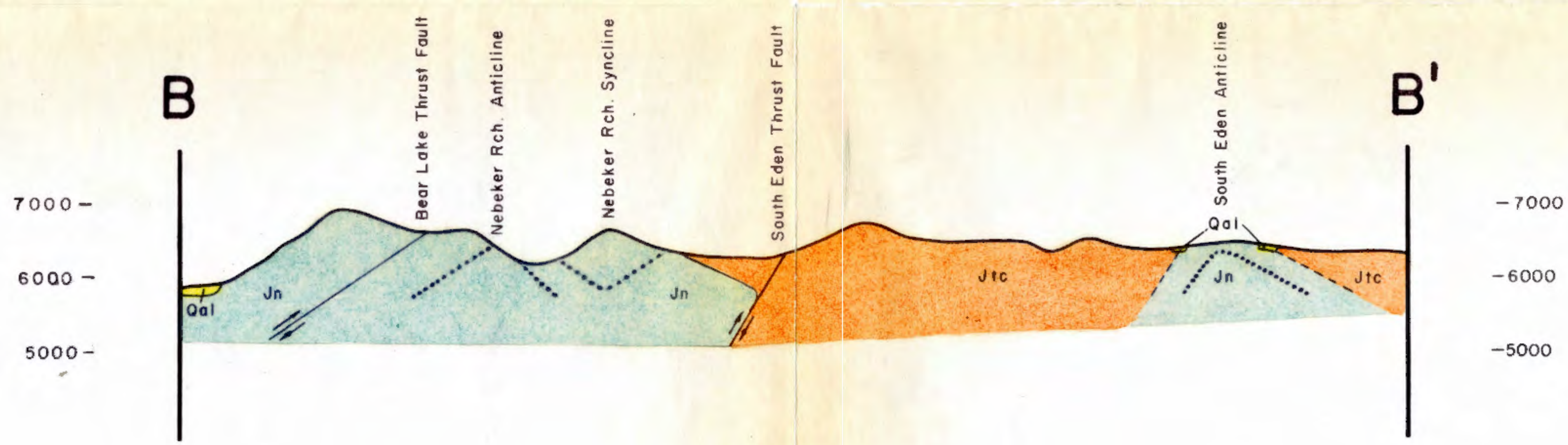
Present Position: Exploration geologist, Amerada-Hess Corporation, Durango, Colorado.



GEOLOGY OF DRAINAGE AREA OF NORTH EDEN CREEK, BEAR LAKE PLATEAU, UTAH - IDAHO

PLATE 2





Location Of Section Are Shown In Plate I
Topographic Profiles From U.S.G.S
Randolph Topographic Quadrangle
1954

EXPLANATION

Contacts (Dashed Where Inferred)

Inferred Bedding Planes

Thrust Fault

GEOLOGIC SECTIONS A-A' & B-B'

BEAR LAKE PLATEAU

UTAH - IDAHO

SCALE 1:24000

1000 0 1000 2000 3000 4000

Larry W. McClurg 1970